AN EVALUATION OF OIL AGGLOMERATION METHODS IN THE RECOVERY AND BENEFICIATION OF PREPARATION PLANT WASTE COAL FINES FROM THE PRINCE MINE

DECLASSIFIED
DATE June 14/88
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MICROMEDIA

DSS File - 12SC.23440-4-9214
Contract Serial Number - 0SC84-00424
for
Energy, Mines and Resources Canada
CANMET, Mineral Sciences Laboratories

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1.0 Introduction

1.1 Background

In early 1984, 400 tons of Prince Mine coal were shipped to the Homer City Coal Cleaning Test Facility for testing under various process configurations considered typical of a coal cleaning facility. This major program was financed by Energy, Mines and Resources Canada.

In late 1984, Scotia Liquicoal Limited, under contract to the Department of Supply and Services, performed a comprehensive laboratory investigation on two samples of Prince Mine waste coal fines. The two samples were taken separately from the feed to the Homer City flotation cells and from the tailings produced by these flotation cells.

The purpose of the laboratory study was to evaluate oil agglomeration methods for the recovery and beneficiation of Prince Mine waste fines. This laboratory investigation included float/sink and sieve analyses as well as oil agglomeration procedures. The results of the investigation were presented in December 1984, under the title "An Evaluation of Oil Agglomeration Methods in the Recovery and Beneficiation of Preparation Plant Waste Coal Fines from the Prince Mine". This report contained a discussion of new proprietary technology for which patent applications were in process. The report was, therefore, treated as confidential.

The laboratory results were encouraging. The oil agglomeration procedure, in combination with a novel product recovery technique introduced and developed by the Chemical Engineering Section of the Division of Chemistry, National Research Council of Canada, provided excellent fines recovery with very favourable levels of ash rejection. The rate of oil addition appeared to be optimum at approximately 1.0%.

On the basis of these results a comprehensive pilot plant evaluation of the agglomeration method and the new product recovery technique was recommended and approved. The purposes of this pilot plant program were to determine the limiting rates of the various unit operations, to optimize operating technique and to characterize continuous pilot plant operation in the recovery and upgrading of the Prince Mine waste coal fines. The results of the pilot plant evaluation were presented in March 1985, under the title "An Evaluation of Oil Agglomeration Methods in the Recovery and Beneficiation of Preparation Plant Waste Coal Fines from the Prince Mine, Phase Two - Pilot Plant Program". This report was also treated as confidential, for the reasons described above.

This report presents a summary of both the lab and the pilot plant programs. All references to proprietary technology are in generalized form. The report need not be treated as confidential.

1.2 Summary and Conclusions

The two samples of Prince Mine fines are referred to as Float Cell Feed and Float Cell Effluent. The samples were received in barrels from the Homer City Coal Cleaning Test Facility. Solids content was approximately 70%. The ash level in the Float Cell Feed sample averaged 41%. The average ash content of the Float Cell Effluent sample was 48%.

Two studies were performed on the Prince Mine samples. A laboratory study involving wet sieve, float/sink and conventional and non-conventional agglomeration procedures was completed. Based on the results of the laboratory study a pilot plant investigation was performed.

The pilot plant program involved pilot scale and bench scale agglomeration methods. Again conventional and non-conventional procedures were tested.

The results of the wet sieve and float/sink testing portion of the laboratory investigation served to characterize the feedstock samples.

The wet sieve analyses showed that approximately 40% of each sample was smaller than 325 mesh. The ash content of the 325 mesh x 0 fraction was 70%. The float/sink analyses confirmed that a large portion of the ash in each sample was liberated, and reported with the 1.6 sink material. The float/sink results also showed that substantial quantities of coal having between 4 and 9% ash were readily available for recovery.

The response of the samples to the agglomeration procedure was then determined.

The best results of the laboratory investigation were achieved using agglomeration followed by newly developed product recovery techniques. For both the Float Cell Feed and the Float Cell Effluent samples the level of #4 oil addition required was approximately 1%. Product ash levels were in the 5 to 6% range. Ash reductions of greater than 87% were achieved.

Combustible recoveries were 84% and 80% for the Float Cell Feed and Float Cell Effluent samples respectively. The settings from the optimum laboratory tests were used as the initial conditions for the pilot plant tests.

The purpose of the pilot plant investigation was to determine the limiting rates of the various unit operations, to optimize operating technique and to characterize continuous pilot plant operation.

The quantity of Prince coal fines available for use during the pilot plant phase of this program was limited. In order to make most effective use of the small quantity of material available the pilot plant work was completed on a batch basis, unit by unit, rather than on a continuous production basis. The batch testing was completed at both bench and plant scale.

Plant scale testing involved preparing a 300 gallon batch of slurry from either the Float Cell Feed or Float Cell Effluent sample. This batch was agglomerated with #2 or #4 oil in a high shear mixer. Additional mixing was provided in a low shear mixer.

Samples withdrawn from the low shear mixer were processed at bench scale using the newly developed product recovery technique. The balance of the agglomerated slurry was processed at pilot plant scale by the same methods.

The main parameters of interest in the plant scale program were slurry solids concentration and high shear/low shear mixer residence time.

Conclusions arising from the pilot plant work are as follows:

- oil agglomeration of either sample of the Prince fines can be carried out effectively at 20% solids. A lower solids level, 10%, provides for better product ash levels.

- product recoveries of approximately 90% are obtainable with good repetition.

- ash rejection is most efficient if recovered product is reslurried in a fresh water wash followed by a second product recovery step. Product ash levels of 5-7% are obtainable.

- most effective agglomeration was obtained using #4 oil, at a level of 1% when processing Float Cell Feed, 1-1/2% when processing Float Cell Effluent. Non-conventional product recovery techniques were far superior to traditional procedures.

- the high shear mixer used by Scotia Liquicoal (60 gallon, 20 HP, initially sized for 5 TPH) appeared to have a limiting feed solids flowrate of 8 TPH. Good agglomeration results were obtained with high shear residence times in the order of 15 seconds.

An important conclusion arising from the more detailed bench scale work completed during the pilot plant program is as follows:

- the operation of the low shear mixer, and residence time in that mixer, are critical only if agglomerate formation is not adequately initiated in the high shear mixer. (insufficient agglomerating oil or inadequate residence time or both)

1.3 Method

During the laboratory investigation four types of tests were performed on each of the Float Cell Feed and Float Cell Effluent samples.

These tests were:

- wet sieve analysis at the following Tyler mesh sizes - 28, 35, 48, 65, 100, 150, 200, 250 and 325.
- float/sink analysis at specific gravities of 1.3 and 1.6
- spherical agglomeration followed by traditional product recovery on screens.
- spherical agglomeration followed by a newly developed product recovery technique.

The wet sieve and float/sink analyses were used to characterize the physical state and ash liberation quality of the samples.

The variables under study in the agglomeration tests, other than product recovery technique, were oil type and oil quantity.

The pilot scale investigation consisted of a series of batch tests performed on each of the two samples (Float Cell Feed and Float Cell Effluent from the Homer City study). The parameters of interest in each test were residence time and solids concentration in the batch mixing equipment.

From the results of the residence time tests at various levels of solids concentration it was possible to determine the limiting rate of solids throughput for each unit of pilot plant equipment tested.

Each batch was processed at plant scale after removing representative samples for detailed bench scale product recovery evaluations.

Section 2.0 of this report describes the testing procedures in greater detail.

1.4 Program

1.4.1 Laboratory Investigation

During November and December 1984, Scotia Liquicoal Limited completed a laboratory study of oil agglomeration methods as applied to the recovery and beneficiation of Prince Mine waste coal fines.

The purpose of this work was to evaluate the effectiveness of oil agglomeration techniques on Prince Mine waste coal fines:

i) to determine whether these waste fines respond favourably to oil agglomeration procedures, and then, if the response was favourable,

ii) to establish the basic operating parameters that result in the best combination of high combustible recovery and low product ash content at minimum cost (i.e. lowest level of oil addition).

Analysis of the laboratory results revealed that the Prince fines did respond well to agglomeration. Most effective recovery of combustibles, with good ash rejection, was obtained using #4 oil as the agglomerating medium. The recently developed NRCC recovery technique proved to be a more effective means of product recovery than the traditional screening method. The required rate of oil addition for effective product recovery was approximately 1%.

1.4.2 Pilot Plant Investigation

The pilot plant investigation was completed during February and March of 1985. The study consisted of a series of batch tests, the main parameters of investigation again being solids concentration and residence time. The oil addition rate was varied during this testing to determine the minimum level of oil addition consistent with acceptable ash reduction and product recovery results.

The following table summarizes the operating conditions for each of the batch tests completed.

TABLE 1.4-1 OUTLINE OF PILOT PLANT TESTS

BATCH NO.	FLOAT CELL FEED	FLOAT CELL EFFLUENT	SOLIDS CONTENT HIGH SHEAR	SOLIDS CONTENT LOW SHEAR	HIGH SHEAR MIXING TIME	OIL CONC. 1%
1	x		20%*	20%	30 sec.	1.0%
2	x		30	30	30	1.0
3	x		30	10	30	1.0
4		x	20	20	30	1.0
5		x	30	30	30	1.0
6		x	30	10	30	1.5
7	x		20	20	30	2.0
8	x		20	20	15	2.0
9	x		20	20	15	1.0
10		x	20	20	30	2.0
11		x	20	20	15	2.0
12		x	20	20	15	1.5

* % means percent by weight

The agglomerated slurry produced in each batch was agitated in the low shear mixer. Samples were withdrawn at preselelcted times over a 10 minute interval.

These samples were subjected to bench scale recovery techniques. The recovered combustibles and the tailings were analysed for moisture, ash and total sulphur.

The balance of each batch was processed at the pilot scale using the newly developed product recovery technique. Recovered combustibles and tailings were analysed for moisture and ash content.

The following sections will explain the overall program in detail.

2.0 Program

2.1 Laboratory Program

Representative samples of the Float Cell Feed and Float Cell Effluent were used in the laboratory investigation. The samples were diluted in separate 5 gallon buckets. Each sample was then mixed for several hours prior to sampling for the following individual tests.

The wet sieve analysis was performed using the following set of Tyler screens 28, 35, 48, 65, 100, 150, 200, 250 and 325 mesh. Once the sample was screened each size fraction was dried, weighed, and analysed for ash content.

The float/sink test was performed by wet screening a large sample on the same set of Tyler screens. The fractions were then separately dispersed in the 1.3 specific gravity medium. After ensuring that all floatable particles had been released from the 1.3 sink material, the float and sink were filtered separately and dried. The float was weighed and analysed for ash content.

The 1.3 sink fraction was subsequently floated in 1.6 specific gravity fluid. The 1.6 float and 1.6 sink cuts were filtered, dried, weighed and analysed for ash content.

This procedure was repeated for each screen fraction of both the Float Cell Feed and Float Cell Effluent samples. The results of these tests will be discussed in Section 3.0 of this report.

The agglomeration procedures involved traditional high speed/low speed mixing of a slurry in the presence of an agglomerating medium. Approximately 50 grams of solids are used in each test. The laboratory agglomerations were carried out at 10% solids, using either #2 or #4 oil as the agglomerating medium.

Recovery of product from the agglomerated tailings slurry was performed by one of two procedures:

i) traditional screening, recovering the agglomerates on a 100 mesh screen and allowing tailings to pass through the screen, or

ii) newly developed recovery techniques.

A number of agglomeration tests were performed on both the Float Cell Feed and the Float Cell Effluent. In addition to varying the oil type, oil quantity and recovery technique a few tests were performed without the standard wash step. The results of these tests will be discussed in detail in Section 3.0.

2.2 Pilot Plant Program

The acceptance of the results and recommendations of the laboratory report enabled a comprehensive pilot scale evaluation to proceed. This study evaluated the response of Prince Mine fines to agglomeration procedures at the pilot scale.

2.2.1 Batch Preparation

FIGURE 2.2-1 shows the flow of Float Cell Feed or Float Cell Effluent slurry through the pilot plant equipment.

The solids content and quantity of slurry for each batch was determined by calculation based on the required solids concentrations in the high shear and low shear mixers.

The Float Cell Feed or Float Cell Effluent sludge, as received from Homer City, was weighed into the blender. Water was added to achieve the the calculated batch conditions. The batch was then mixed in the blender for 1-2 hours prior to agglomeration in the high shear.

The solids content of the batch was the same as that required in the high shear (see TABLE 1.4-1). The volume of the batch was 300 gallons in each case except for batches #3 and #6, which were only 100 gallons. This allowed for subsequent dilution of these two batches.

2.2.2 Batch Agglomeration and Sampling

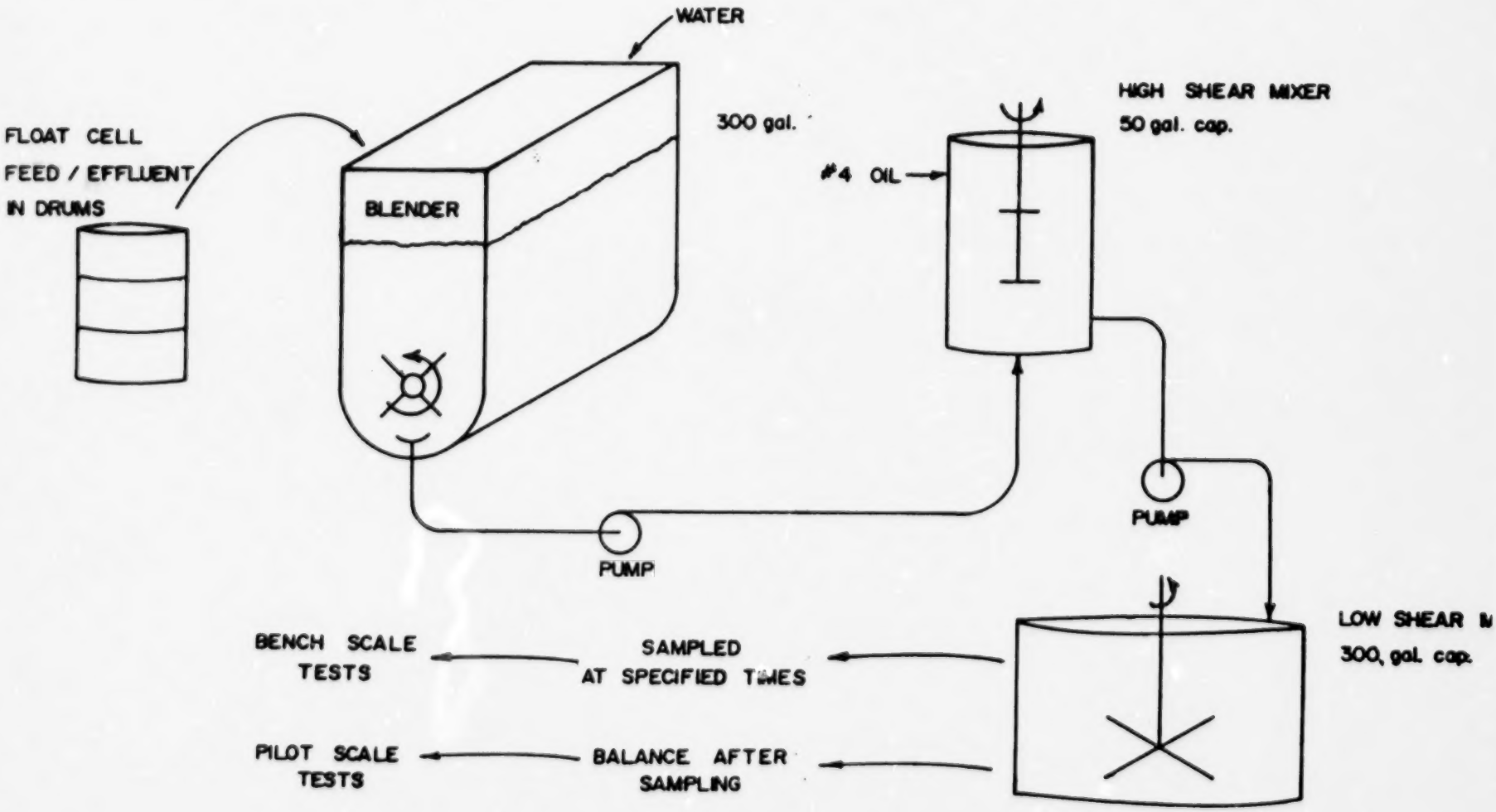
Each batch was pumped in 50 gallon lots to the high shear mixer where the required amount of oil was added prior to mixing. After mixing for the prescribed time (15 or 30 seconds) the slurry was pumped to the low shear mixer and the procedure was repeated.

Once the low shear mixer was filled to its 300 gallon capacity (either by 6 high shear lots or by 2 lots and subsequent dilution for Batches 3 and 6) the mixer was turned on. One 5 gallon sample was removed at each of the following time: 0, 30 seconds, 1 minute, 2 minutes, 5 minutes and 10 minutes. The total quantity of sample material removed was 30 gallons, or 10% of the 300 gallon batch. Test results were not adversely affected by this sampling procedure.

These 5 gallon samples were then used in bench scale testing of the agglomerated slurry. This testing procedure is described in Section 2.3. The balance of the batch (approximately 270 gallons) was processed at the pilot plant scale as described in Section 2.2.4.

FIG. 2.1-1

BATCH PREPARATION / PILOT AGGLOMERATION SYSTEM



2.2.3 Bench Scale Sample Processing

The timed samples taken from the low shear mixer were processed by th novel recovery techniques using bench sized equipment.

The bench scale testing included processing the agglomerated slurries "as is" as well as diluting the slurries to lower solids contents before processing. The solids concentrations under investigation wer 30%, 20% and 10% by weight. That is, if the agglomerated slurry was initially at 30% solids, then fresh water dilution to 20% or 10% woul be carried out for subsequent tests at these levels.

Retention time for product recovery was limited to 2 minutes. After minutes processing the recovered product and tailings were weighed an sampled for moisture ash and sulphur determinations.

The kinetics of the recovery process were also tested during this program. The products recovered during the four 30 second intervals from time=0 to retention time=2 minutes were collected separately and analysed individually.

Other tests performed during this bench evaluation involved reslurrying recovered product in fresh water and performing a wash. Recovery of product after this step was done by either screening or a novel product recovery technique.

2.2.4 Plant Scale Batch Processing

The remainder of each batch (270 gallons) of agglomerated slurry was processed in the pilot plant equipment using the novel recovery process. The main steps in the process are shown in FIGURE 2.2-2.

The agglomerated slurry was drained from the low shear mixer to the batch-type pilot scale recovery unit in two steps. First, 180 to 200 gallons of agglomerated slurry was processed. After product recovery was completed the tailings were pumped to a water clarifier.

The remaining 70 to 90 gallons of agglomerated slurry was drained to the recovery unit and diluted to approximately 200 gallons with fresh water. This dilution reduced the solids concentration for the second step of processing to roughly one half that of the first step of processing.

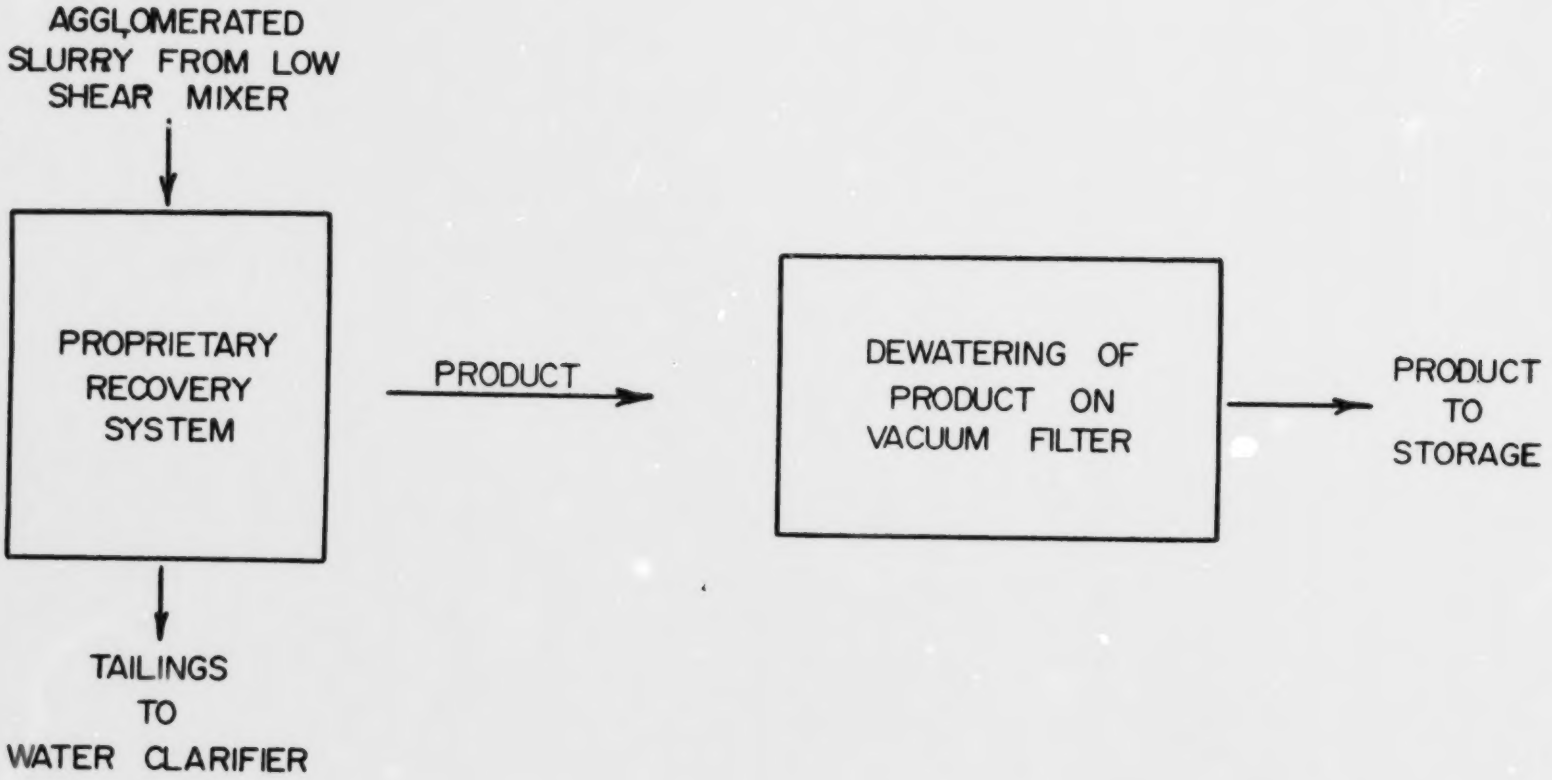
Samples of recovered product and rejected tailings were taken during both processing steps. Moisture and ash analyses were performed on each sample.

After the remaining 70 to 90 gallons of agglomerated slurry had been drained to the recovery unit, the high shear and low shear mixers were ready to process the next batch of agglomerated slurry.

The final stage of plant scale work involved testing the confidential recovery process in a continuous processing unit. The unit was installed and the following procedure was performed for each of two tests, one performed on the Float Cell Feed and the second performed on the Float Cell Effluent sample.

FIG: 2.2-2

PLANT SCALE BATCH PROCESSING



- The recovery unit and the low shear mixer were charged with agglomerated slurry at 10% solids concentration. Operation of the unit was stabilized by continually recirculating and remixing the recovered product and the tailings in the low shear mixer.

- Once equilibrium was deemed to have been reached samples of recovered product and tails were taken for moisture and ash tests.

The continuous processing system arrangement is shown in FIGURE 2.2-3.

3.0 Results and Discussion

3.1 Laboratory Results

3.1.1 Physical Characteristics of Feedstocks

The two samples were received in the form of moist filter cake from the Homer City Coal Cleaning Test Facility. The solids content of both samples were in the 65-70% by weight range. The ash content of the Float Cell Feed was nominally 41% while the ash content of the Float Cell Effluent was 48% by weight.

One barrel of each sample was mixed by shovel and a sample was taken. The Float Cell Feed and Float Cell Effluent samples were diluted separately in 5 gallon buckets.

These slurries served as the stock for the laboratory investigation. The stock slurries were mixed by a variable speed lab mixer prior to sampling for the tests described in Section 2.1.

The wet sieve analysis on the Float Cell Feed showed an average of 39.3% smaller than 325 mesh, 47.5% smaller than 200 mesh, and a mass mean particle diameter of 84 microns. The Float Cell Effluent averaged 41.8% smaller than 325 mesh, 50.6% smaller than 200 mesh and a mass mean particle diameter of 72 microns.

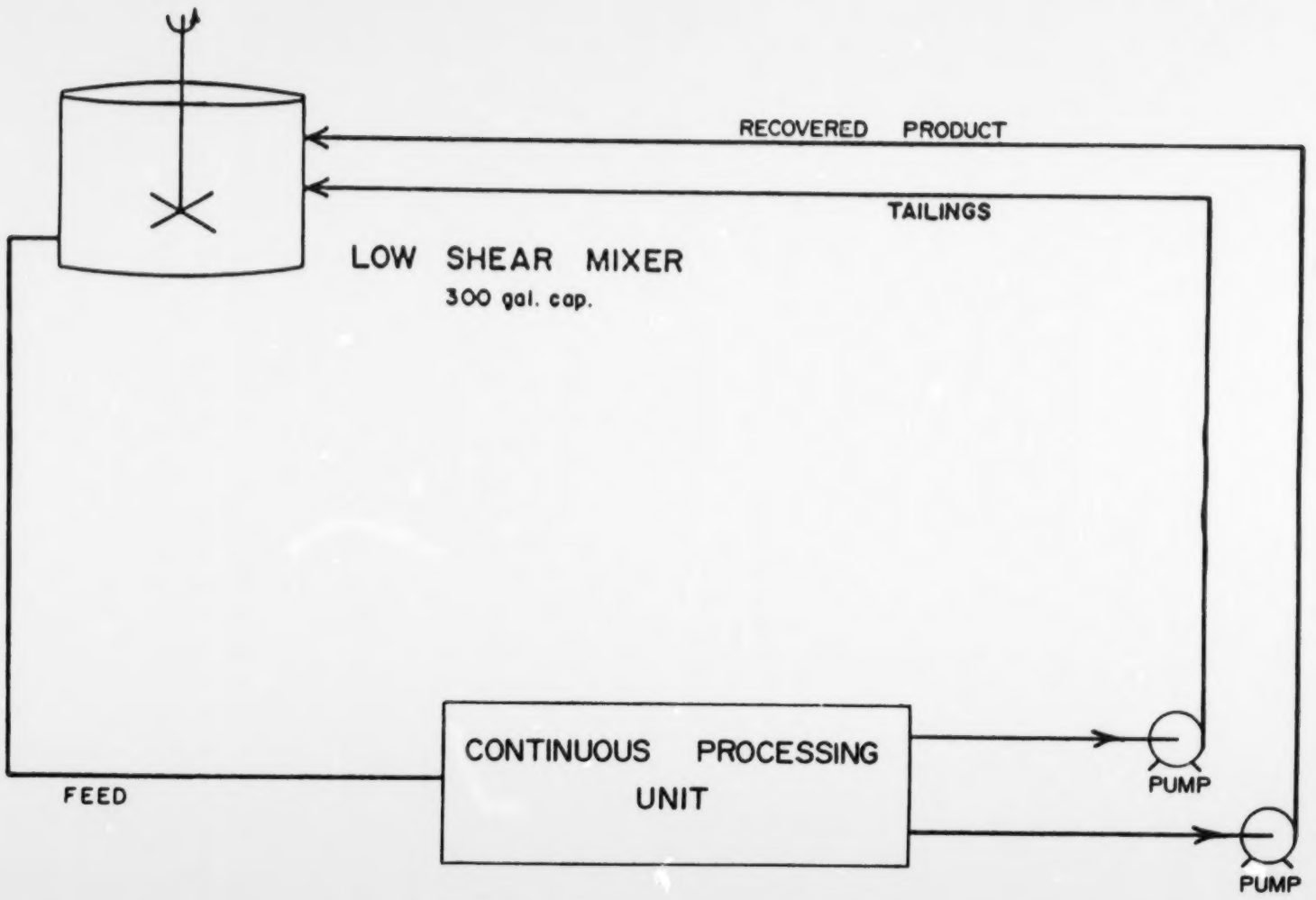
The samples were tested as received from Homer City. There was no size reduction performed on either sample prior to testing.

The size and ash distribution tables (see TABLES 3.1-1 and 3.1-2) show that there was more coarse material in the Float Cell Effluent sample than there was in the Float Cell Feed sample.

The two samples handled in much the same manner. Both samples were very difficult to wet sieve because of the abundance of clay in the -325 mesh fraction. This fine clay tended to blind or plug up even some of the coarser screens, causing flooding of the screens during the size analysis. Screening was performed slowly and carefully to accommodate the fines.

3. 2.2-3

CONTINUOUS PILOT PLANT PROCESSING SYSTEM



SAMPLE NO. Flotation Cell Feed
Average

SIZE & ASH DISTRIBUTION

SIZE (TYLER MESH)	Wt %	CUM Wt %	ASH %	CUM ASH %	COMBUSTIBLES %	CUM COMBUSTIBLES %
+28	2.90	2.90	50.43	50.43	2.45	2.45
28/35	2.64	5.54	53.83	52.05	2.08	4.53
35/48	6.42	11.96	27.83	39.06	7.90	12.44
48/65	12.83	24.79	19.67	29.02	17.59	30.02
65/100	11.36	36.16	14.37	24.42	16.60	46.62
100/150	8.66	44.81	12.66	22.15	12.90	59.52
150/200	7.70	52.51	16.40	21.30	10.98	70.50
200/250	2.64	55.15	21.23	21.30	3.55	74.05
250/325	5.57	60.72	33.54	22.42	6.31	80.37
-325	39.28	100.0	70.70	41.38	19.63	100.00

TABLE 3.1-1

SAMPLE NO. Flotation Cell Effluent
Average

SIZE & ASH DISTRIBUTION

SIZE (TYLER MESH)	Wt %	CUM Wt %	ASH %	CUM ASH %	COMBUSTIBLES %	CUM COMBUSTIBLES %
+28	5.45	5.45	35.72	35.72	6.73	6.73
28/35	4.22	9.67	49.16	41.59	4.13	10.86
35/48	6.05	15.72	41.54	41.57	6.80	17.65
48/65	10.61	26.34	32.41	37.88	13.788	31.44
65/100	9.32	35.65	24.27	34.32	13.56	45.00
100/150	7.02	42.67	17.64	31.58	11.11	56.10
150/200	6.79	49.46	18.00	29.72	10.69	66.80
200/250	2.62	52.08	23.14	29.38	3.88	70.67
250/325	6.22	58.30	32.74	29.74	8.04	78.71
-325	41.70	100.0	73.43	47.96	21.29	100.00

TABLE 3.1-2

3.1.2 Float/Sink Analysis

TABLES 3.1-3 and 3.1-4 present the float/sink test results for the Float Cell Feed and FLoat Cell Effluent samples respectively. The tables give the screen-by-screen breakdown of weight percent, ash percent and combustibles recovered for each of the float/sink fractions.

The Float Cell Feed and Float Cell Effluent samples show considerable amounts of material floating at both 1.3 and 1.6 specific gravity. The cumulative ash percentages for the 1.3 FLOATS and the 1.6 FLOATS are 1.7 - 2.1% and 8.0 - 8.5% respectively. Comparison of these ash levels to the feedstock ash contents of 41 and 48% shows that the majority of the ash in both the Float Cell Feed and the Float Cell Effluent is liberated.

If the 1.6 SINK material could be removed effectively from each sample then the remaining clean coal would have an ash content of under 5%. Recovery of combustibles for this case (i.e. 1.6 SINK material removed) would be greater than 85% after both the Float Cell Feed and the Float Cell Effluent.

3.1.3 Traditional Agglomeration Results

The results of the agglomeration tests incorporating traditional screening to recover product are presented in TABLES 3.1-5 and 3.1-6 for the Float Cell Feed and the Float Cell Effluent respectively.

Comparing the results of the tests using #2 oil to those using #4 oil shows that, for both samples, #4 oil agglomeration gave a much higher combustible recovery while maintaining comparable product ash levels. The Float Cell Feed sample was cleaned to product ash levels near 15%.

The high ash content in the recovered product resulted from the coarse ash retained by the agglomerate screening step. It is possible that grinding the sample could render the coarse ash fine enough to pass through the agglomerate collection screen. This grinding could also liberate combustible material and thereby increase recovery.

The first row in each table presents the "agglomeration" results at an oil level of 0%. The results are not markedly different from the tests that used #2 oil, proving that for these samples traditional agglomeration procedures are more effective when using #4 oil.

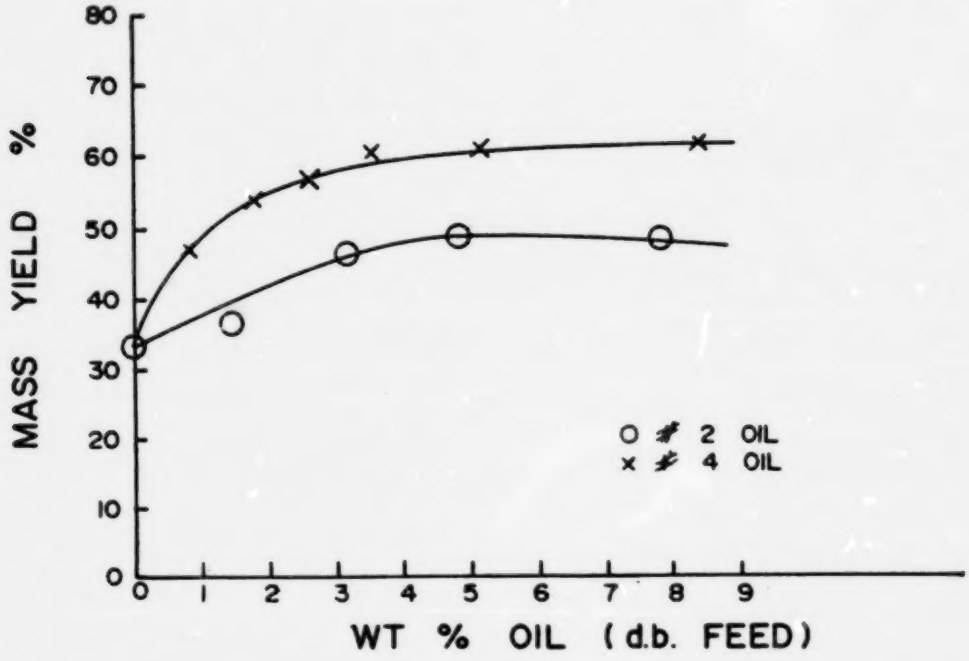
The trends discussed above are clearly shown in FIGURES 3.1-1, 3.1-2 and 3.1-3.

3.1.4 Agglomeration

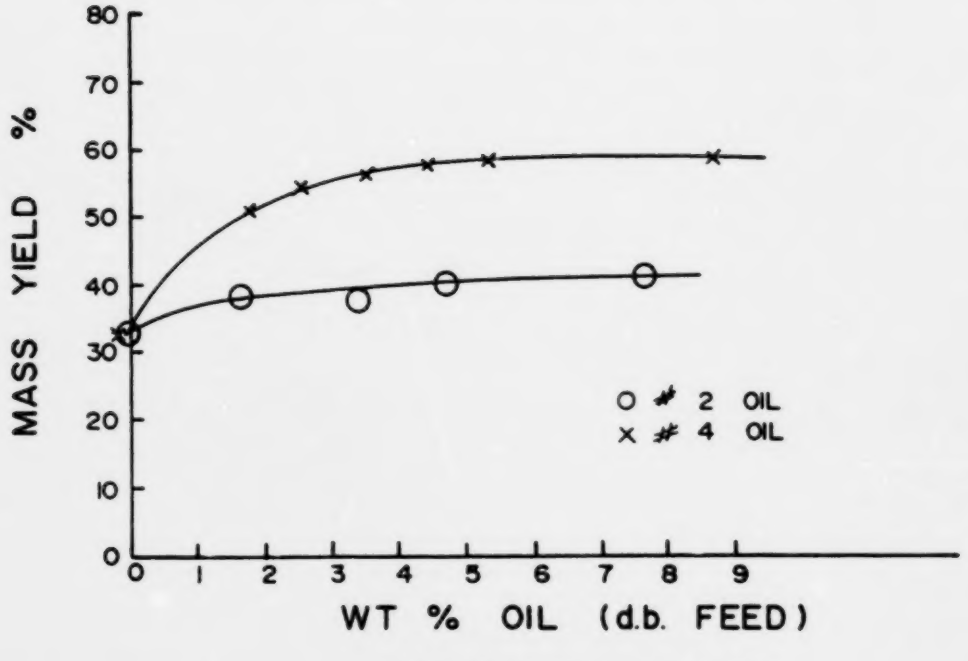
The data and derived results for the agglomeration tests incorporating the new recovery techniques are presented in TABLES 3.1-7 and 3.1-8.

Poor combustible recoveries are obtained when using #2 oil. The three main advantages of using #4 oil and the novel recovery methods are:

AGGLOMERATION & SCREENING

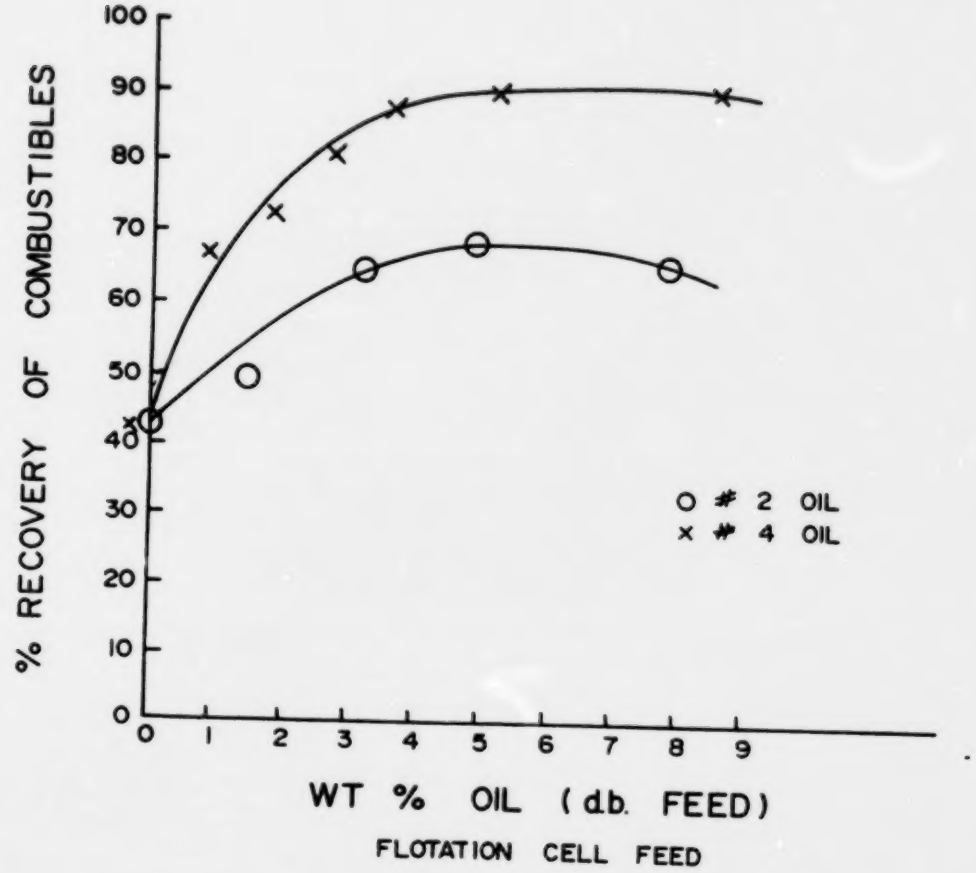


FLOTATION CELL FEED

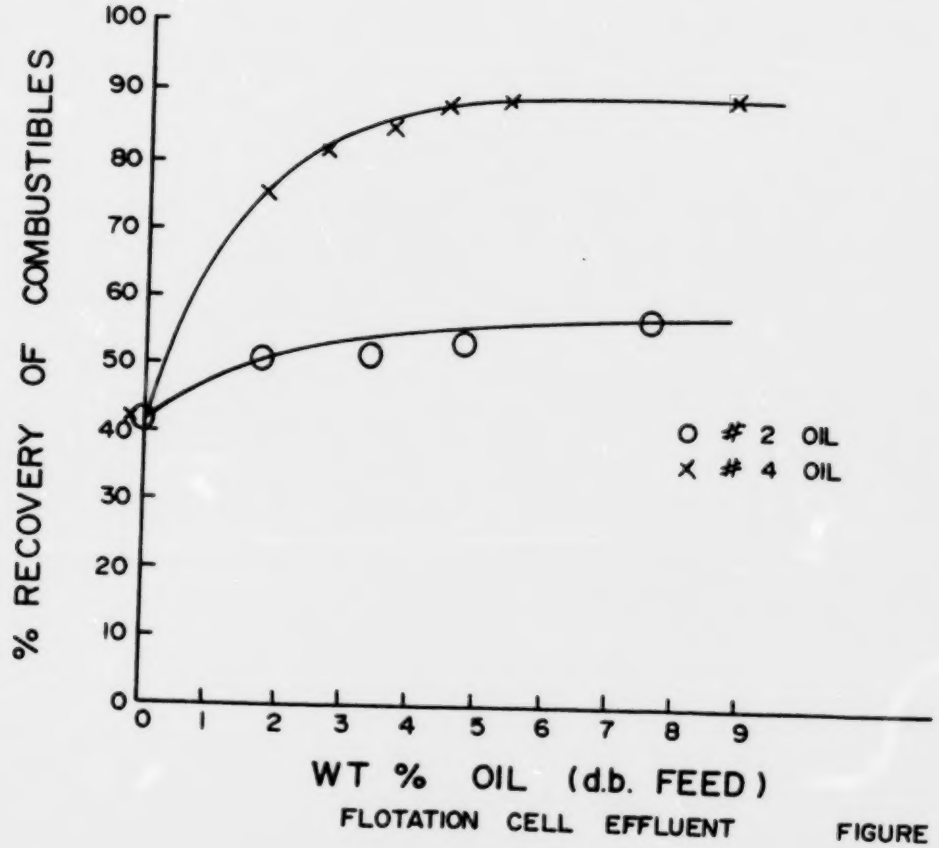


FLOTATION CELL EFFLUENT

FIGURE 3.3-2



FLOTATION CELL FEED



FLOTATION CELL EFFLUENT

FIGURE 3.3-3

SAMPLE FLOTATION CELL FEED
Average

% of TOTAL SAMPLE	45.07%						22.42%						32.51%					
SIZE TYLER MESH	1.30 gm/cc FLOATS						1.30-1.60 gm/cc FLOATS						1.60 gm/cc SINKS					
	Wt %	CUM Wt %	% ASH	CUM % ASH	% COMB	CUM % COMB	Wt %	CUM Wt %	% ASH	CUM % ASH	% COMB	CUM % COMB	Wt %	CUM Wt %	% ASH	CUM % ASH	% COMB	CU % CO
+28	0.67	0.67	2.22	2.22	0.67	0.67	3.56	3.56	17.00	17.00	3.21	3.21	7.59	7.59	65.91	65.91	9.70	9.
28/35	0.91	1.58	1.59	1.86	0.91	1.58	2.06	5.62	14.59	16.12	1.92	5.13	7.80	15.38	71.91	68.95	8.22	12.
35/48	10.65	12.23	1.68	1.70	10.67	12.25	6.76	12.38	10.75	13.19	6.57	11.70	10.12	25.50	81.13	73.78	7.16	25.
48/65	27.49	39.72	1.93	1.86	27.47	39.72	14.51	26.88	10.58	11.78	14.13	25.83	12.33	37.83	82.66	76.67	8.02	33.
65/100	26.09	65.81	1.86	1.86	26.09	65.81	14.18	41.06	9.50	10.99	13.97	39.80	8.30	46.13	76.37	76.62	7.36	40.
100/150	19.64	85.45	1.81	1.85	19.65	85.45	13.06	54.13	8.04	10.28	13.08	52.88	5.69	51.82	68.94	75.78	6.63	47.
150/200	12.25	97.70	1.93	1.86	12.24	97.70	17.45	71.57	5.92	9.22	17.88	70.76	6.69	58.51	70.69	75.20	7.35	54.
200/250	0.86	98.56	1.62	1.86	0.86	98.56	9.44	81.01	4.16	8.63	9.85	80.60	2.50	61.01	67.88	74.90	3.01	57.
250/325	1.43	100.0	1.95	1.86	1.44	100.00	18.99	100.0	6.20	8.17	19.40	100.00	9.42	70.43	75.84	75.02	8.53	65.
-325	0						0						29.57	100.0	69.34	73.34	34.01	100.

TABLE 3.1-3 FLOAT/SINK ANALYSIS OF FLOTATION CIRCUIT FEED

SAMPLE FLOTATION CELL EFFLUENT
Average

% of TOTAL SAMPLE	34.48%						19.30%						46.22%					
SIZE TYLER MESH	1.30 gm/cc FLOATS						1.30-1.60 gm/cc FLOATS						1.60 gm/cc SINKS					
	Wt %	CUM Wt %	% ASH	CUM % ASH	% COMB	CUM % COMB	Wt %	CUM Wt %	% ASH	CUM % ASH	% COMB	CUM % COMB	Wt %	CUM Wt %	% ASH	CUM % ASH	% COMB	CUM % COMB
+28	4.75	4.75	2.82	2.82	4.71	4.71	11.02	11.02	17.04	17.04	10.00	10.00	8.46	8.46	66.30	66.30	12.16	12.
28/35	3.79	8.54	1.85	2.39	3.79	8.51	3.70	14.73	13.31	16.10	3.51	13.51	7.00	15.46	73.82	69.71	7.82	19.9
35/48	8.73	17.27	2.15	2.27	8.72	17.23	4.91	19.63	12.41	15.18	4.70	18.21	8.31	23.77	83.17	74.41	5.92	25.9
48/65	24.14	41.41	2.05	2.14	24.14	41.37	10.98	30.62	10.98	13.67	10.69	28.90	13.48	37.25	87.58	79.18	7.14	33.0
65/100	25.83	67.25	2.05	2.11	25.83	67.21	8.66	39.28	10.99	13.08	8.43	37.33	8.18	45.44	82.12	79.71	6.25	39.3
100/150	19.66	86.90	1.75	2.03	19.72	86.93	8.23	47.50	8.70	12.32	8.21	45.54	4.77	50.21	75.33	79.29	5.02	44.3
150/200	9.45	96.36	2.20	2.04	9.44	96.37	21.31	68.82	4.55	9.92	22.25	67.79	4.43	54.63	69.79	78.52	5.71	50.0
200/250	1.91	98.26	1.88	2.04	1.91	98.28	6.12	74.94	4.34	9.46	6.40	74.19	1.52	56.20	69.07	78.26	2.07	52.1
250/325	1.74	100.0	2.80	2.05	1.72	100.00	25.06	100.0	5.82	8.55	25.81	100.00	7.29	63.49	77.62	78.19	6.96	59.0
-325	0						0						36.51	100.0	73.73	76.56	40.92	100.0

TABLE 3.1-4 FLOAT/SINK ANALYSIS OF FLOTATION CIRCUIT EFFLUENT

SAMPLE FLOTATION CELL FEED

Agglomeration: Traditional Procedure

	WEIGHT %	OIL	PRODUCT			TAILS			
	(d.b. prod)	(d.b. feed)	% ASH d.b.	MASS YIELD %	COMB REC %	% ASH(db)	ASH REJ %	% ASH in Feed	PULP DENSITY %
#2 Oil	0	0	26.87	33.87	42.94	50.23	78.49	42.32	10.29
	1.49	4.08	22.94	36.52	49.62	54.99	80.65	43.29	11.03
	3.16	6.75	20.78	46.80	64.65	61.89	77.20	46.65	10.39
	4.88	9.95	16.65	49.10	69.10	64.03	79.95	40.77	10.09
	7.82	16.04	20.42	48.75	66.69	62.19	76.20	41.83	10.50
#4 Oil	0.86	1.81	14.10	47.80	67.42	62.00	82.77	39.11	10.25
	1.74	3.34	15.25	52.19	73.56	66.74	80.03	39.87	10.17
	2.64	4.61	26.19	57.25	81.80	76.53	72.95	44.85	10.06
	3.55	5.84	15.47	60.88	88.79	83.40	77.60	42.05	9.96
	5.12	8.26	16.55	61.98	90.63	85.94	76.11	42.93	10.37
	8.48	13.63	22.96	62.17	91.24	87.85	69.95	47.51	10.44

TABLE 3.1-5

SAMPLE FLOTATION CELL EFFLUENT

Agglomeration: Traditional Procedure

	WEIGHT %	OIL	PRODUCT			TAILS			
	(d.b. feed)	(d.b. feed)	% ASH d.b.	MASS YIELD %	COMB REC %	% ASH(db)	ASH REJ %	% ASH in Feed	PULP DENSITY %
#2 Oil	0	0	36.10	32.77	42.37	57.64	76.61	50.58	10.41
	1.70	4.44	32.22	38.29	50.46	58.70	74.59	48.56	9.66
	3.41	8.94	28.61	38.10	52.44	60.14	77.35	48.13	9.64
	4.79	12.22	30.43	39.32	53.58	61.10	75.67	49.07	10.27
	7.68	18.56	28.07	41.38	57.30	62.15	75.82	48.05	10.69
#4 Oil	1.71	3.30	22.33	51.81	76.32	74.09	75.53	47.27	10.34
	2.56	4.69	20.45	54.53	81.82	78.80	76.26	46.98	10.39
	3.54	6.27	21.25	56.56	85.76	82.97	74.99	48.06	9.99
	4.42	7.73	19.09	57.21	87.67	84.79	76.86	47.20	10.01
	5.30	9.19	20.16	57.66	88.94	86.48	75.90	48.24	10.02
	8.73	14.93	19.65	58.50	89.77	87.09	75.87	47.64	10.13

TABLE 3.1-6

SAMPLE FLOTATION CELL FEED

Agglomeration: Confidential Procedure

	WEIGHT % OIL		PRODUCT			TAILS			
	(d.b. feed)	(d.b. feed)	% ASH d.b.	MASS YIELD %	COMB REC %	% ASH(db)	ASH REJ %	% ASH in Feed	PULP DENSITY %
#2 Oil	0	0	0	0	0	42	100	42	10
	2.29	7.05	3.71	32.45	53.19	59.28	97.08	41.25	10.77
	4.60	18.39	3.56	25.01	41.10	53.90	97.84	41.31	10.71
#4 Oil	0.33	7.50	6.74	4.46	7.15	43.28	99.28	41.84	10.59
	0.70	1.38	4.96	50.39	84.07	81.71	94.19	43.03	10.16
	1.03	1.96	5.36	52.59	83.61	79.42	93.03	40.47	10.31
	1.74	3.24	6.13	53.55	87.11	83.99	92.24	42.30	10.20
	3.41	6.35	4.17	53.78	88.87	86.03	94.66	42.00	10.37
	4.87	8.82	6.69	55.20	90.26	87.60	91.40	42.94	10.91
#4 Oil Not Washed	0.84	1.56	8.28	53.55	85.94	82.70	89.65	42.85	10.56
	1.67	3.01	8.95	55.62	87.56	83.78	88.19	42.16	10.58
	2.54	4.46	9.56	57.08	89.59	86.03	87.12	42.38	10.43

TABLE 3.1-7

SAMPLE NO. Flotation Cell Effluent

Agglomeration: Confidential Procedure

	WEIGHT % OIL		PRODUCT			TAILS			
	(d.b. feed)	(d.b. feed)	% ASH d.b.	MASS YIELD %	COMB REC %	% ASH(db)	ASH REC %	% ASH in Feed	PULP DENSITY %
#2 Oil	0	0	0	0	0	48	100	48	10
	5.13	24.22	4.37	21.17	26.63	29.28	96.15	24.01	9.61
	8.11	45.51	3.15	17.81	26.65	42.23	98.41	35.27	10.13
#4 Oil	0.88	2.71	4.80	32.61	58.56	67.41	96.67	46.99	10.00
	1.22	2.70	5.86	45.09	80.79	81.62	94.43	47.46	10.18
	1.81	4.09	6.30	44.33	79.18	80.38	94.13	47.54	9.77
	3.54	7.50	7.33	47.26	84.83	85.15	92.84	48.37	9.99
	5.28	10.92	7.16	48.36	86.52	86.46	92.80	48.11	10.05
#4 Oil Not Washed	1.23	2.55	10.41	48.37	84.17	84.22	89.62	48.52	10.05
	1.61	3.27	11.46	49.23	85.54	85.49	88.50	49.05	10.99
	2.46	4.99	12.00	49.22	85.47	85.50	88.02	49.32	10.81

TABLE 3.1-8

i) a low amount of oil is required.

ii) the recovered product has a low ash content.

iii) good combustible recoveries are achieved.

The ash contents of the recovered products are in the 5-6% range for both the Float Cell Feed and the Float Cell Effluent samples. This represents a significant reduction in ash content compared to the traditional procedure.

The last three rows in each table present the results of tests that did not incorporate a wash step. The ash content of the recovered product is considerably higher than in the "washed" results.

The curves in FIGURES 3.1-4, 3.1-5 and 3.1-6 are similar to those presented in the previous section. Although the product ash content using #2 oil is quite low the recovery of combustibles is also very low.

In FIGURE 3.1-7 a comparison between tradition and confidential procedures is presented in bar graph form for the Float Cell Feed sample using 2% #2 oil and #4 oil. The new recovery techniques gave a much lower ash level in the product. Combustible recovery is also much higher when using #4 oil and the proprietary methods.

FIGURE 3.1-8 shows, in a similar manner, the optimum test results obtained using each procedure. Substantially less oil is required for the procedure. Substantially less oil is required for the new recovery procedure while maintaining or surpassing the product grade and recovery obtainable using traditional procedures.

The following section will discuss the results of the pilot plant work, which was based on the results of the laboratory investigation.

3.2 Pilot Plant Results

3.2.1 Bench Scale Tests

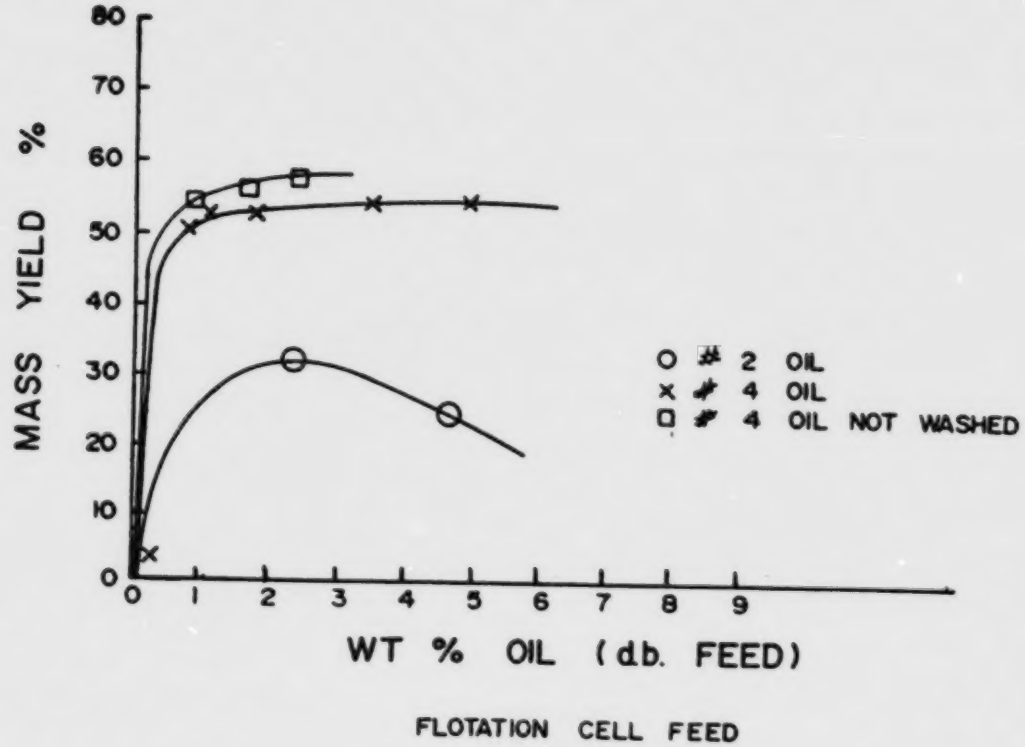
Section 2.2.3 describes the two basis tests done on the agglomerated samples taken from the low shear mixer after a predetermined period of mixing.

These were as follows:

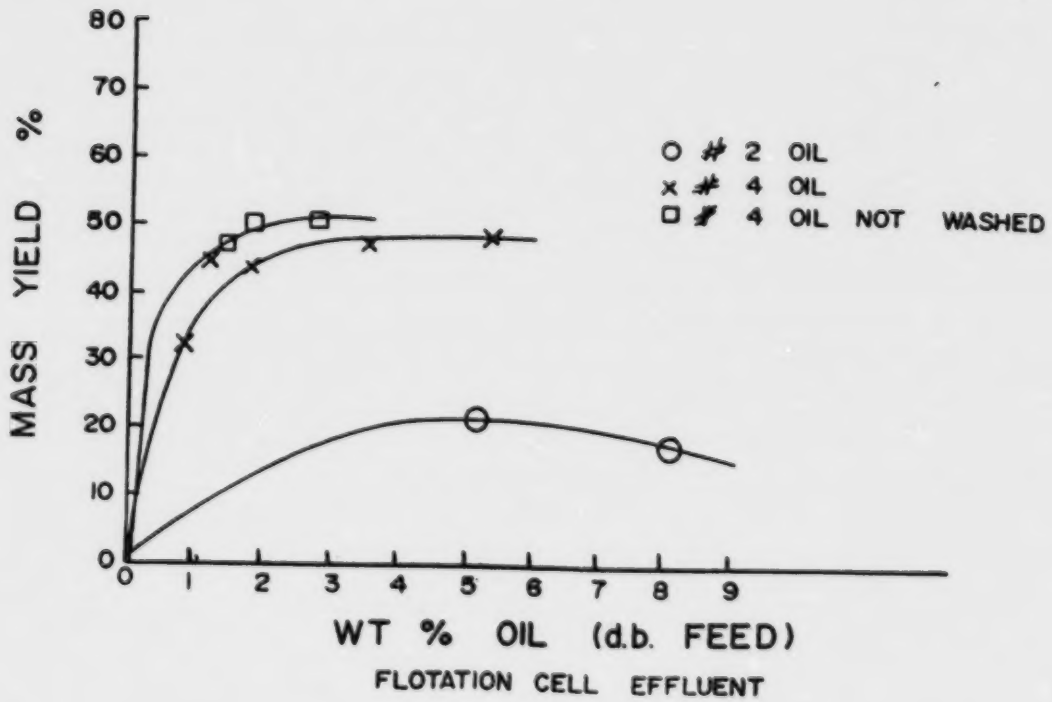
i) a "routine" test, which involved product recovery using the confidential recovery methods for 2 minutes, and

ii) a "kinetics" test, which included the collection of product in separate containers over 4 successive 30 second time intervals.

AGGLOMERATION : CONFIDENTIAL PROCEDURE



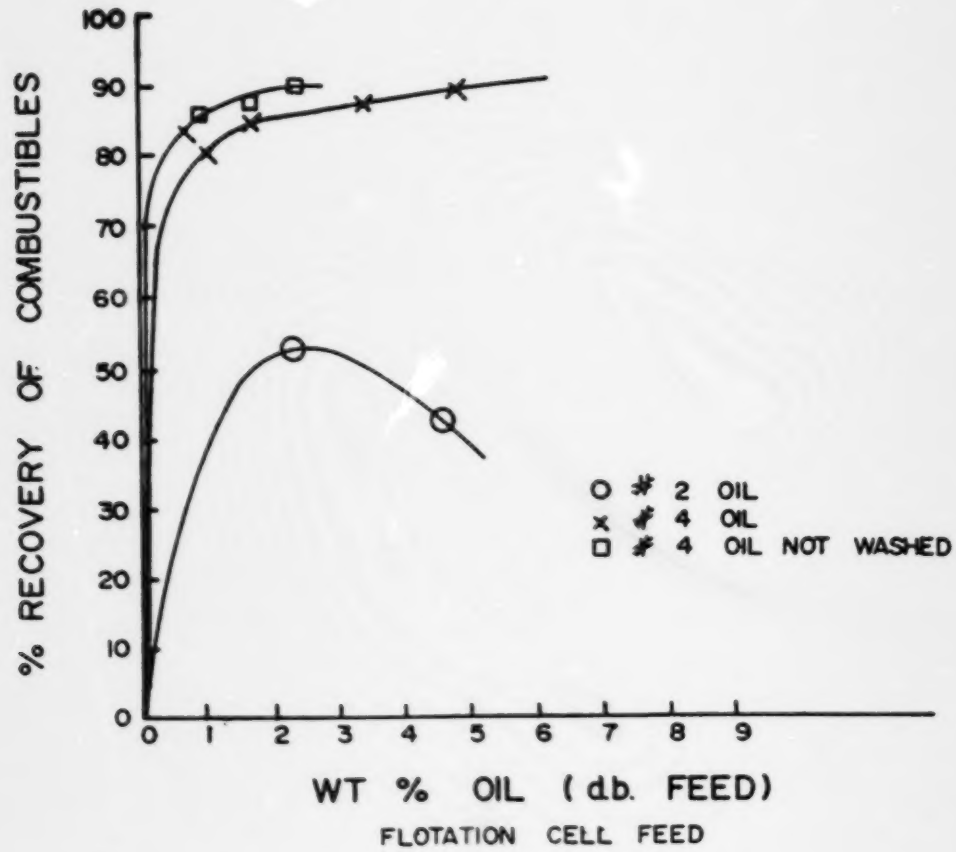
FLOTATION CELL FEED



FLOTATION CELL EFFLUENT

FIGURE 3.1-5

AGGLOMERATION : CONFIDENTIAL PROCEDURE



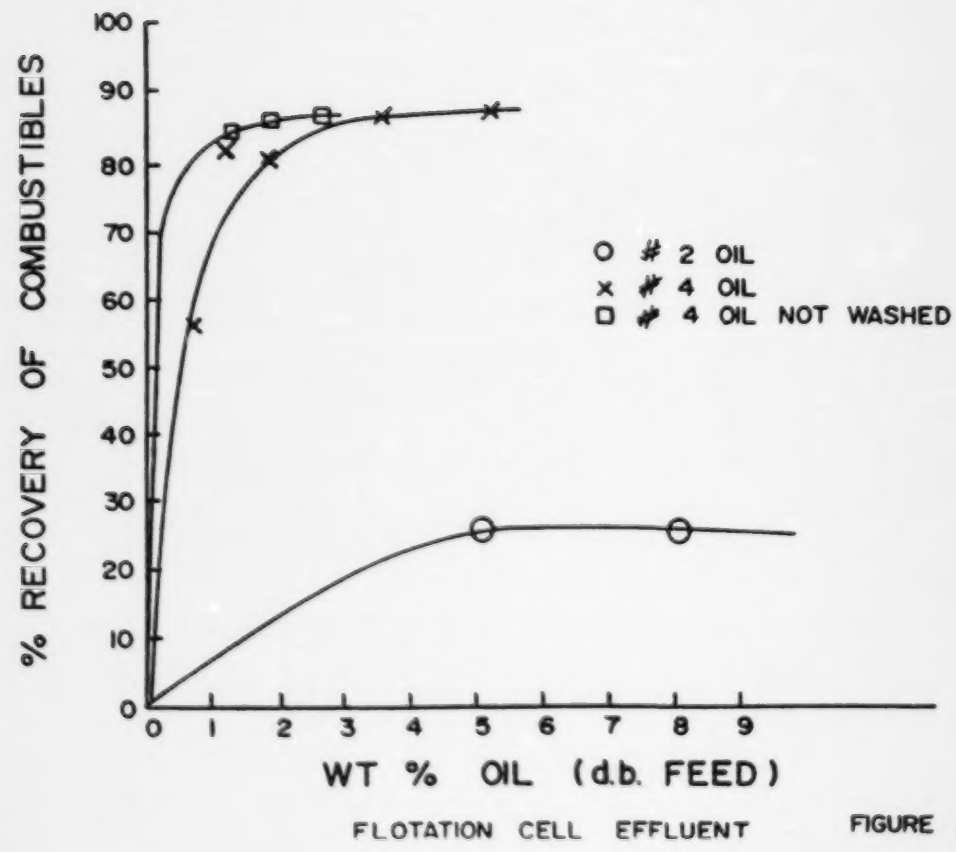
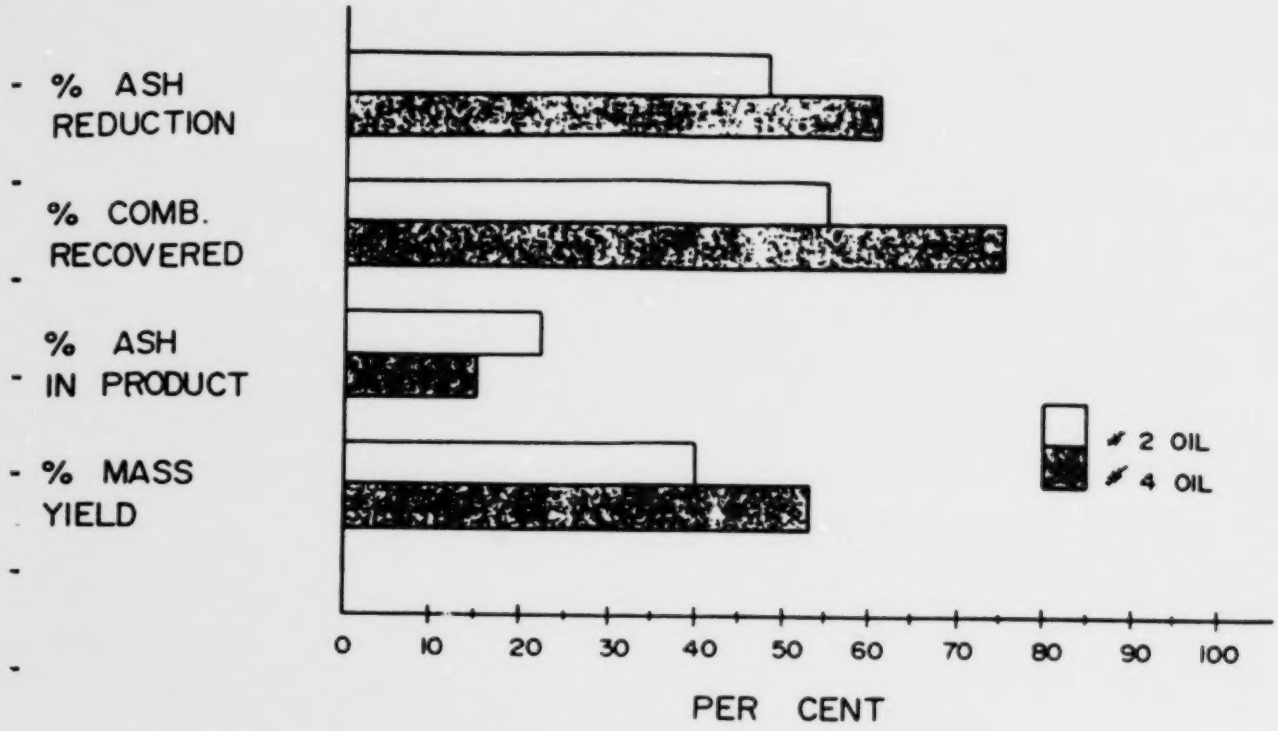


FIGURE 3.1-6

TRADITIONAL AGGLOMERATION



AGGLOMERATION : CONFIDENTIAL PROCEDURE

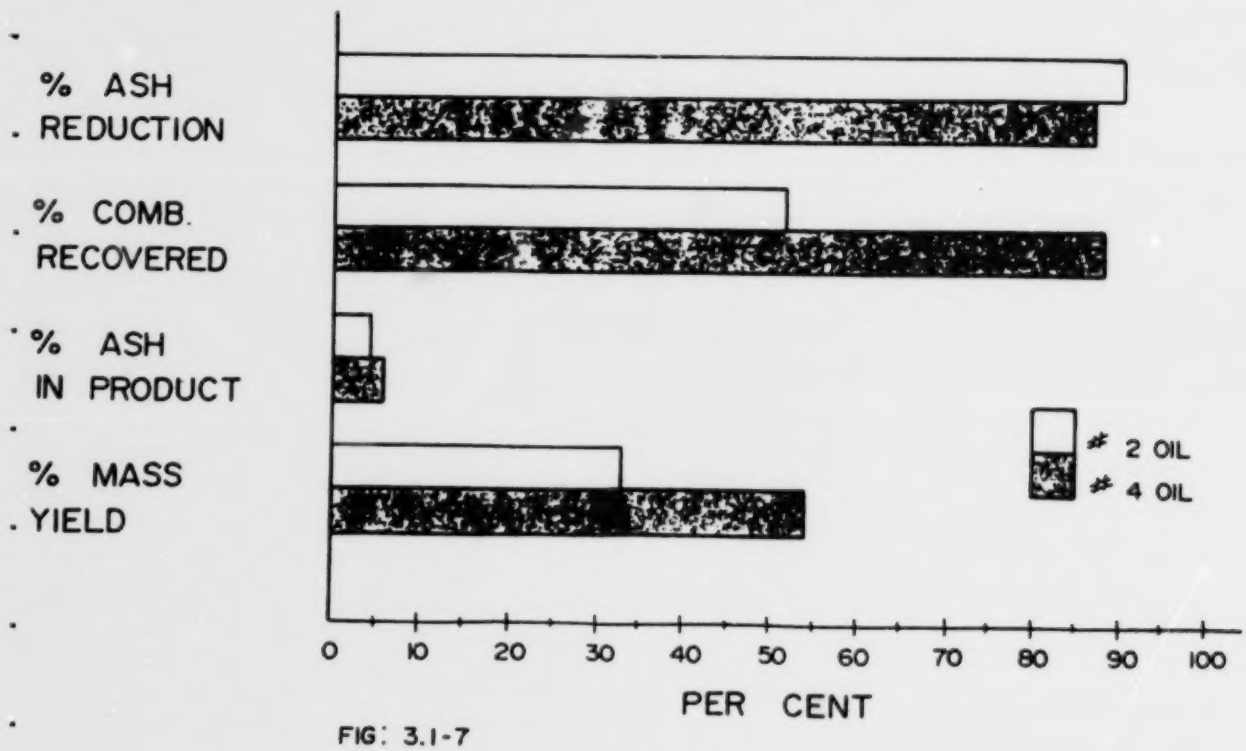


FIG: 3.1-7

TRADITIONAL AND AGGLOMERATION : CONFIDENTIAL PROCEDURE FOR THE FLOTATION CELL FEED SAMPLE 2 AND 4 OIL (D.B. FEED)

TRADITIONAL AGGLOMERATION VS CONFIDENTIAL PROCEDURE

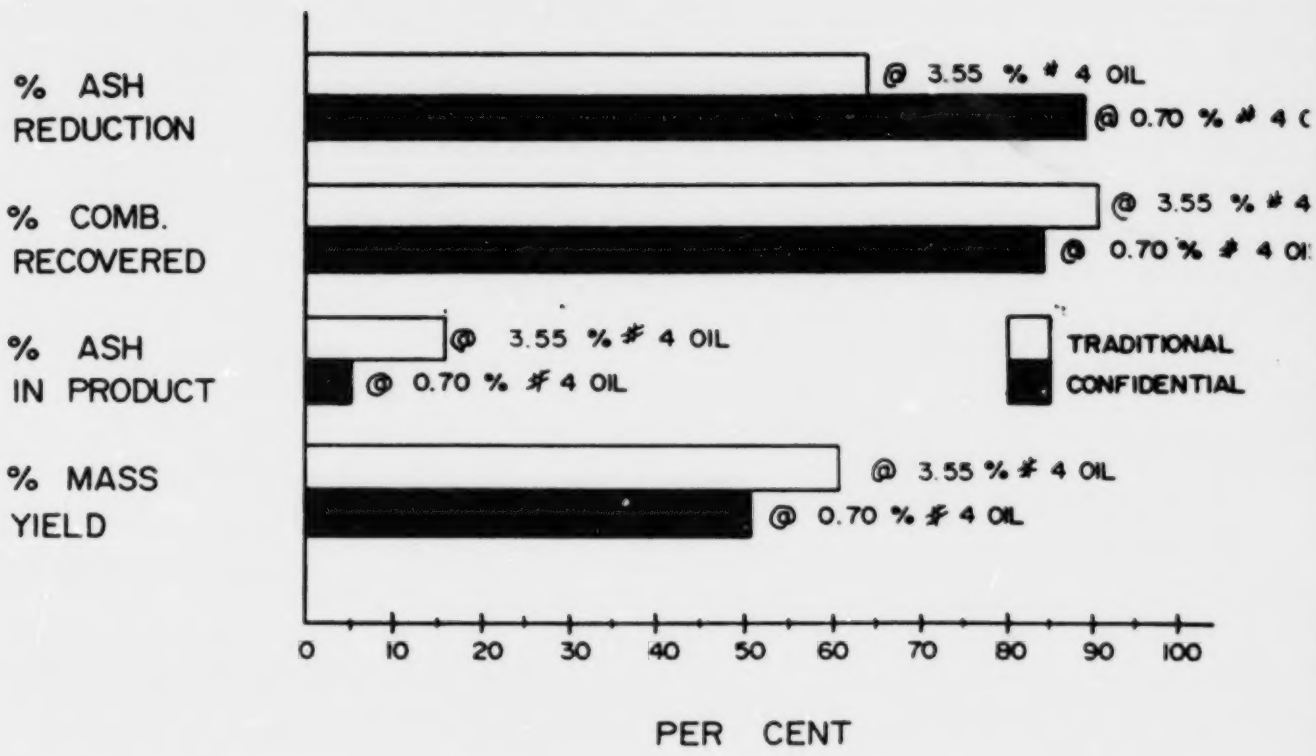

% ASH REDUCTION
% COMB. RECOVERED
% ASH IN PRODUCT
% MASS YIELD
@ 3.55 % # 4 OIL
@ 0.70 % # 4 C
@ 3.55 % # 4
@ 0.70 % # 4 OI
@ 3.55 % # 4 OIL
@ 0.70 % # 4 OIL
@ 3.55 % # 4 OIL
@ 0.70 % # 4 OIL
TRADITIONAL
CONFIDENTIAL
0 10 20 30 40 50 60 70 80 90 100
PER CENT

FIG: 3.1 - 8 OPTIMUM RESULTS USING TRADITIONAL AGGLOMERATION AND AGGLOMERATION : CONFIDENTIAL PROCEDURE ON FLOTATION CELL FEED.

The recovered product and tailings from each test were weighed and samples for moisture, ash and total sulphur content analyses.

The analytical results for batches 1 - 6 are presented in TABLES 3.2 to 3.2-6. These tables include the results of mass balance calculations, e.g. mass yield, combustible recovery, ash rejection. Note that sulphur is expressed on a mineral matter free (MM Free) basis to avoid "dilution" effects of the ash percentage in the sampl.

The important results of the bench scale work can be summarized as follows:

- agglomeration at 20% solids yields slightly better results than agglomeration at 30% solids.
- when agglomerating at 30% solids subsequent dilution in the low shear mixer improves recovery, allowing greater combustible recoveries in shorter residence times.
- mixing time in the low shear mixer does not appear to play very important role in achieving good recovery for most of the batches.
- for a high shear residence time of 30 seconds it appears that 1% #4 oil is sufficient for the Float Cell Feed but 1.5% #4 oil is required for good recovery on the Float Cell Effluent sample.

Each of the above points can be seen by comparison of the various curves in FIGURES 3.2-1, 3.2-2 and 3.2-3. Notice how "flat" most of the curves are, suggesting that residence time in the low shear is not a critical operating parameter at these oil levels.

In testing Batch 5 agglomerated slurries it was noticed that the oil level should be increased slightly. A slightly higher oil level was used in Batch 6. Better combustible recoveries were achieved.

The intent of the testing for Batches 7 - 12 was to decrease the residence time in the high shear mixer to determine the maximum throughput rate of the unit. The analytical results of these batches are given in TABLES 3.2-7 through 3.2-12.

There is a noticeable drop in the ash content of the product from Batch 7 to Batch 9 with a corresponding drop in combustible recovery and tailings ash content. A similar but less pronounced effect is noticed in the data for Batch 10 to Batch 12.

FIGURES 3.2-4, 3.2-5 and 3.2-6, show that combustible recovery for Batches 7 and 8 varies little over time. The combustible recovery for Batch 9, which has a lower oil content than Batch 8, is very time dependent.

TABLE 3.2-1

FLOTATION CELL FEED - MASS BALANCE RESULTS
Agglomerated with 1.0% Oil
at 20% Solids

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
1	0-B	1.00	1.61	12.43	3.12	61.99	87.60	79.78	79.74	28.83	56.70	38.03	6.31	11.21
1	0-A	1.00	1.56	16.72	3.81	64.00	86.55	76.98	72.14	24.50	50.02	38.41	6.59	19.30
1	30-A	1.00	1.50	18.01	3.79	66.60	89.84	81.51	69.41	30.67	47.76	39.22	6.52	19.45
1	30-B	1.00	1.71	11.35	3.24	58.43	84.86	77.76	82.97	22.53	55.39	38.95	6.16	10.95
1	1-A	1.00	1.49	18.54	3.90	66.90	89.30	80.26	68.17	28.77	46.91	38.97	6.57	19.39
1	1-B	1.00	1.61	11.83	3.08	62.15	88.27	80.75	80.61	26.60	53.41	37.91	5.84	10.99
1	2-A	1.00	1.87	15.46	3.41	53.56	82.71	79.62	81.70	26.89	62.26	45.26	7.47	17.40
1	2-B	1.00	1.54	14.57	3.24	64.78	89.50	81.56	75.27	28.58	50.85	38.17	5.90	10.63
1	5-A	1.00	1.54	15.94	3.57	64.81	89.12	81.10	73.42	29.63	50.33	38.87	6.40	18.88
1	5-B	1.00	1.56	13.03	3.36	63.90	90.19	83.26	78.30	32.02	50.90	38.38	6.17	10.96
1	10-A	1.00	1.57	16.81	3.62	65.88	90.49	83.13	71.92	33.55	49.34	39.44	6.46	18.89
1	10-B	1.00	1.52	11.45	3.14	65.95	90.34	81.66	78.64	26.17	47.13	35.36	5.36	9.40

TABLE 3.2-2a

FLOTATION CELL FEED - MASS BALANCE RESULTS
Agglomerated with 1.0% #4 Oil
at 30% Solids

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
2	0-A	1.00	1.46	22.73	4.06	68.53	85.11	70.56	58.77	17.19	42.53	37.78	6.02	29.73
2	0-B	1.00	1.55	17.22	3.43	64.50	85.14	73.76	70.22	18.98	49.11	37.29	5.74	21.25
2	0-C	1.00	1.65	13.24	2.89	60.76	83.83	74.09	78.33	18.33	55.00	37.12	5.39	12.52
2	30-A	1.00	1.48	22.53	4.21	67.73	84.03	69.10	59.37	16.96	43.36	37.56	6.24	29.45
2	30-B	1.00	1.59	16.77	3.58	62.78	83.61	72.48	71.93	19.19	51.23	37.51	6.14	20.99
2	30-C	1.00	1.66	12.57	3.15	60.40	83.29	73.24	79.25	18.76	54.48	36.60	5.76	12.16
2	1-A	1.00	1.47	22.81	4.04	67.92	84.50	70.02	59.18	16.74	43.18	37.96	6.01	29.71
2	1-B	1.00	1.48	18.61	3.74	67.73	88.27	77.30	66.43	22.56	44.52	37.55	5.94	21.56
2	1-C	1.00	1.59	13.06	2.88	62.93	86.31	76.59	77.55	20.46	53.03	36.61	5.28	11.88
2	2-A	1.00	1.39	23.31	4.16	71.79	88.41	74.40	55.63	20.23	38.95	37.72	6.02	29.37
2	2-B	1.00	1.50	18.60	3.60	66.80	87.17	75.90	66.97	21.78	47.10	37.62	5.93	21.79
2	2-C	1.00	1.60	14.39	2.96	62.37	85.93	76.77	76.30	21.39	54.24	37.87	5.55	12.44
2	5-A	1.00	1.39	23.11	4.04	72.09	88.28	73.64	55.23	20.98	40.78	37.21	6.03	28.88

TABLE 3.2-2b

FLOTATION CELL FEED - MASS BALANCE RESULTS
Agglomerated with 1.0% #4 Oil
at 30% Solids

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
2	5-B	1.00	1.50	17.71	3.34	66.67	88.17	77.91	68.75	24.90	50.00	37.78	5.89	19.79
2	5-C	1.00	1.60	13.70	2.94	62.57	85.97	76.45	76.95	21.66	54.57	37.19	5.57	10.43
2	10-A	1.00	1.37	23.41	4.01	73.13	89.32	75.08	54.10	22.03	39.65	37.29	5.93	28.52
2	10-B	1.00	1.42	19.53	3.65	70.74	91.10	80.99	63.17	28.62	43.36	37.51	5.88	20.78
2	10-C	1.00	1.49	14.81	3.12	67.29	90.98	82.62	73.06	29.46	48.34	36.99	5.50	10.78

TABLE 3.2-3

FLOTATION CELL FEED - MASS BALANCE RESULTS
Agglomerated with 1.0% #4 oil
at 30% solids and diluted
to 10% solids in low shear mixer

		Wt % Oil		Product				Tails						
Batch	Sample	d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.	% Ash in Feed	% S in Feed MM Free	Pulp Density
3	0-A	1.00	1.57	13.13	3.74	63.59	89.35	81.91	78.13	27.31	46.54	38.17	6.25	10.65
3	30-A	1.00	1.58	14.62	3.90	63.25	88.82	81.50	76.41	28.16	47.61	39.20	6.61	10.63
3	1-A	1.00	1.56	13.47	3.62	63.96	89.86	82.67	77.57	29.20	47.67	38.41	6.21	10.34
3	2-A	1.00	1.58	13.67	3.98	63.31	89.14	81.85	77.63	27.27	45.47	38.68	6.51	10.52
3	5-A	1.00	1.55	14.46	3.32	64.68	91.24	84.96	76.24	34.18	49.71	39.36	6.02	10.33
3	10-A	1.00	1.54	14.43	3.53	64.99	92.35	86.83	76.42	37.36	46.74	39.77	6.12	10.60

TABLE 3.2-4

FLOTATION CELL EFFLUENT - MASS BALANCE RESULTS
Agglomerated with 1.0% #4 oil
at 20% solids

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
4	0-A	1.00	1.27	19.18	4.50	51.60	78.54	76.46	78.90	22.43	57.63	46.90	8.35	18.54
4	0-B	1.00	2.05	14.19	3.86	48.83	76.10	74.28	84.58	18.47	60.06	44.94	7.35	10.55
4	30-A	1.00	1.93	19.45	4.47	51.86	78.58	76.35	78.47	22.33	57.66	46.84	8.29	18.47
4	30-B	1.00	2.17	15.03	3.27	46.18	72.01	71.66	84.75	16.55	66.28	45.51	6.99	10.59
4	1-A	1.00	1.97	19.60	4.12	50.81	77.88	76.41	79.05	22.64	60.96	47.54	8.21	18.71
4	1-B	1.00	1.98	14.99	3.58	50.47	79.13	77.16	83.48	22.29	62.17	45.78	7.48	11.30
4	2-A	1.00	1.91	19.64	4.17	52.45	78.00	75.00	77.59	20.32	57.89	45.96	7.72	18.01
4	2-B	1.00	1.99	15.54	3.49	50.26	74.64	71.00	81.89	15.59	60.26	43.13	6.56	11.15
4	5-A	1.00	1.73	21.08	4.32	57.74	82.37	76.93	72.76	21.85	51.97	44.68	7.41	17.72
4	5-B	1.00	1.84	17.81	3.66	54.42	79.31	74.40	77.77	18.36	56.67	43.60	6.70	11.80
4	10-A	1.00	1.72	21.38	4.46	58.19	83.23	77.96	72.38	23.32	51.28	45.04	7.63	18.00
4	10-B	1.00	1.84	17.66	4.17	54.23	82.77	79.69	79.21	23.29	53.79	46.05	7.46	10.35

TABLE 3.2-5

FLOTATION CELL EFFLUENT - MASS BALANCE RESULTS
Agglomerated with 1.0% #4 oil
at 30% solids

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
5	0-A	1.00	3.84	20.91	3.74	26.04	38.93	56.30	88.43	10.62	81.66	47.08	7.94	26.47
5	0-B	1.00	3.70	22.04	3.66	27.04	41.26	58.86	87.81	11.59	81.87	48.90	8.32	21.69
5	0-C	1.00	2.91	15.35	2.99	34.42	50.01	55.58	87.34	8.76	74.55	41.73	5.87	10.00
5	30-B	1.00	4.52	22.60	3.46	22.13	32.18	53.63	89.30	9.40	85.13	46.76	7.49	16.86
5	30-C	1.00	3.06	16.21	3.08	32.70	47.22	54.49	87.37	8.37	75.25	41.97	5.87	10.09
5	1-A	1.00	3.27	23.93	3.80	30.59	42.68	54.99	83.91	10.49	78.75	45.49	7.63	25.76
5	1-C	1.00	2.66	14.80	3.20	37.55	54.81	57.76	86.65	9.04	69.94	41.63	5.84	10.16
5	2-B	1.00	3.44	18.04	2.98	29.10	43.89	57.00	88.50	10.07	81.21	45.66	6.96	16.68
5	2-C	1.00	3.08	13.02	2.87	32.42	50.47	59.05	90.44	10.26	77.79	44.13	6.53	10.08
5	5-B	1.00	2.09	23.82	4.15	47.80	60.99	55.37	71.74	9.52	59.49	40.29	6.24	20.18
5	5-C	1.00	1.94	14.65	2.94	51.43	83.97	82.74	84.21	28.68	65.06	47.72	7.07	8.49
5	10-A	1.00	3.20	19.96	3.86	31.29	47.69	60.02	86.85	11.91	77.18	47.48	8.07	26.68
5	10-B	1.00	2.49	16.87	3.27	40.15	59.26	61.66	84.49	11.87	71.38	43.68	6.77	17.95

TABLE 3.2-6

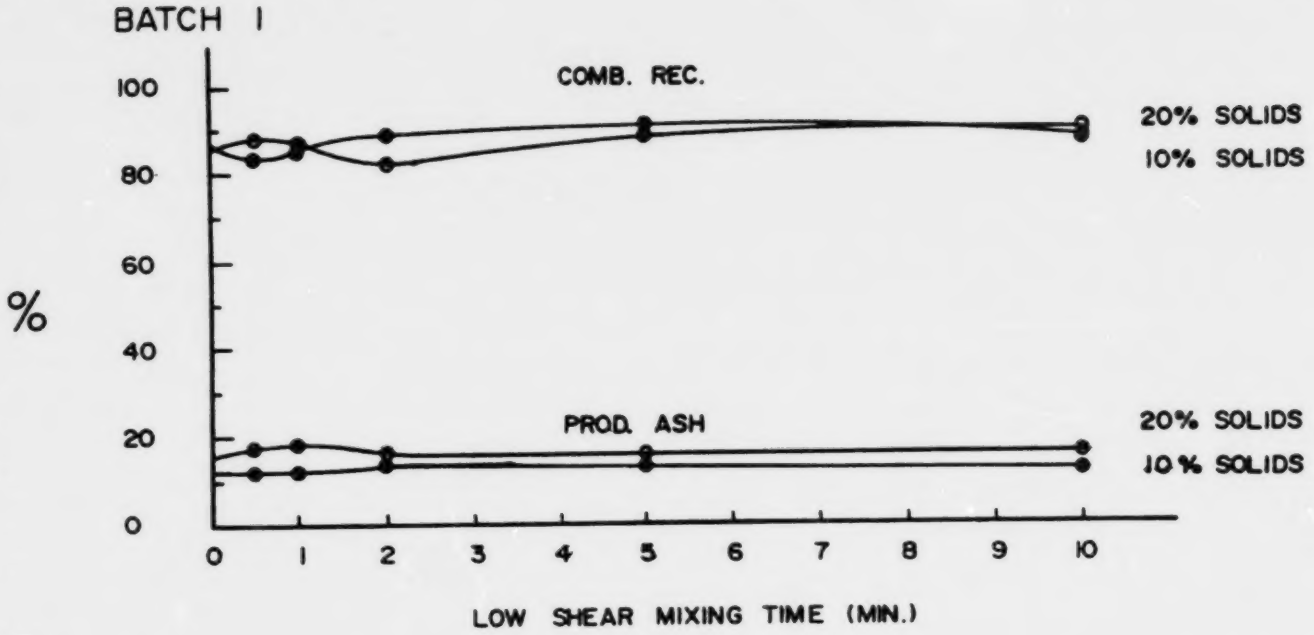
FLOTATION CELL EFFLUENT - MASS BALANCE RESULTS
Agglomerated with 1.5% #4 oil at 30% solids and diluted to 10% solids in low shear mixer

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
6	0-A	1.50	2.48	16.09	3.53	60.36	88.27	83.02	77.21	29.80	52.88	42.62	6.61	11.01
6	30-A	1.50	2.58	14.36	3.54	58.05	86.21	81.04	80.31	25.11	53.17	42.34	6.51	10.64
6	1-A	1.50	2.75	15.82	3.64	54.64	74.43	65.15	77.37	11.71	52.53	38.19	5.70	12.07
6	2-A	1.50	2.49	16.77	3.50	60.34	87.69	82.23	76.32	27.24	52.23	42.73	6.42	10.54
6	5-A	1.50	2.61	15.52	3.68	57.44	86.44	82.12	79.68	29.59	55.76	43.86	7.19	11.46
6	10-A	1.50	2.37	18.23	4.79	63.34	89.60	83.60	72.63	28.84	41.12	42.19	7.29	11.21

FIG. 3.2-1

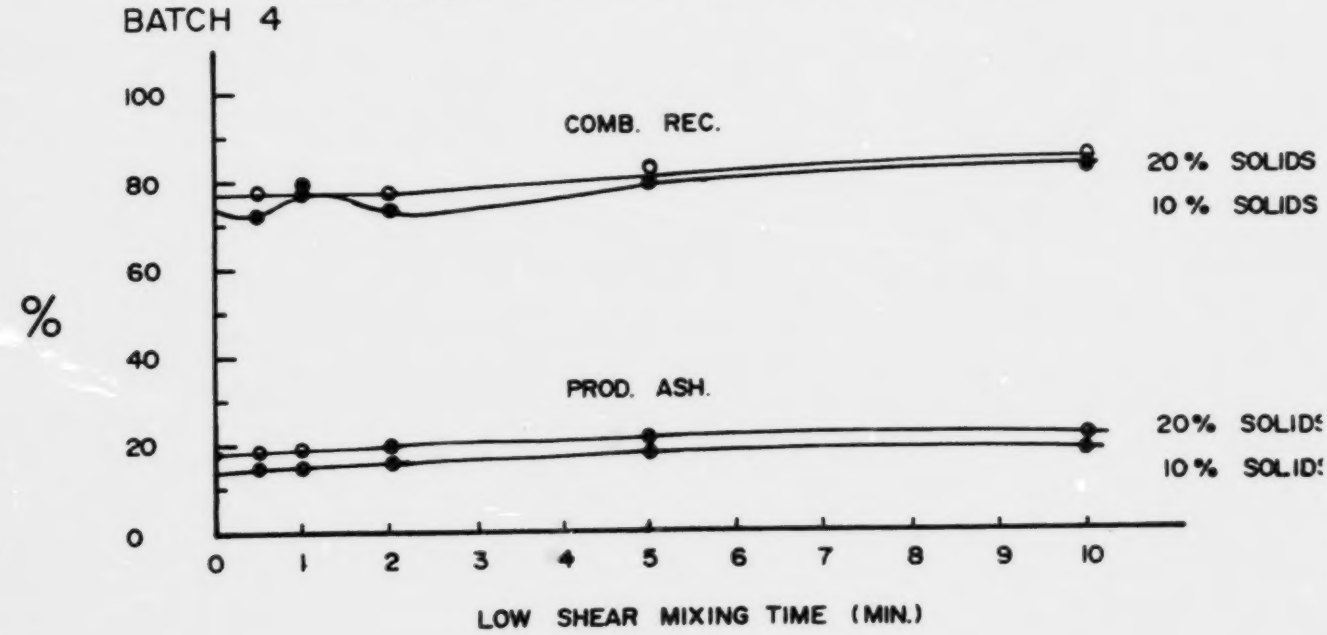
FLOTATION CELL FEED

AGGLOMERATED WITH 1.0% #4 OIL AT 20% SOLIDS



FLOTATION CELL EFFLUENT

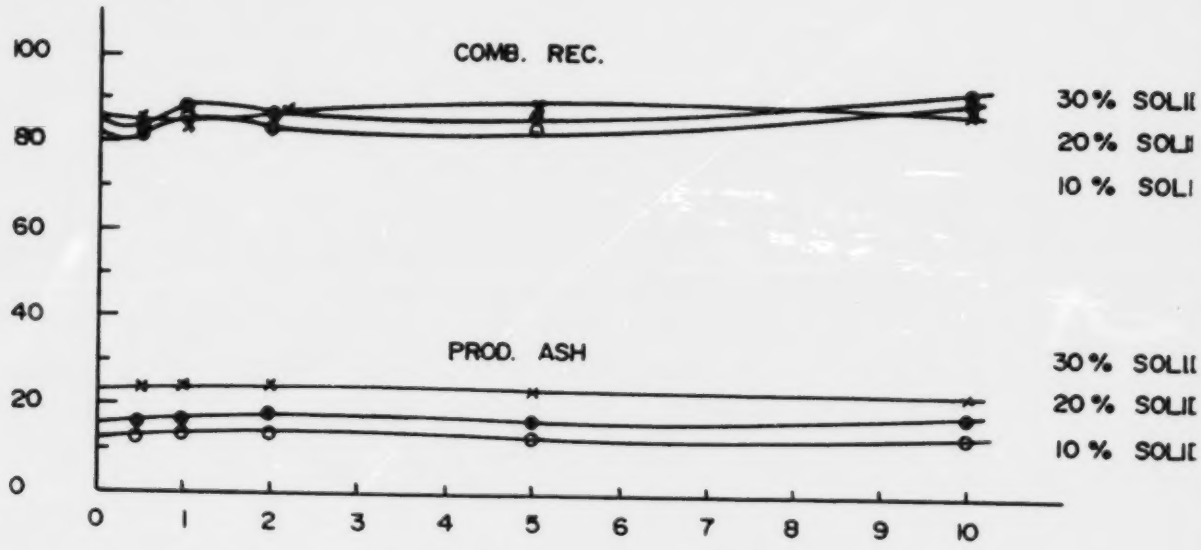
AGGLOMERATED WITH 1.0% #4 OIL AT 20% SOLIDS



FLOTATION CELL FEED

AGGLOMERATED WITH 1.0% #4 OIL AT 30% SOLIDS

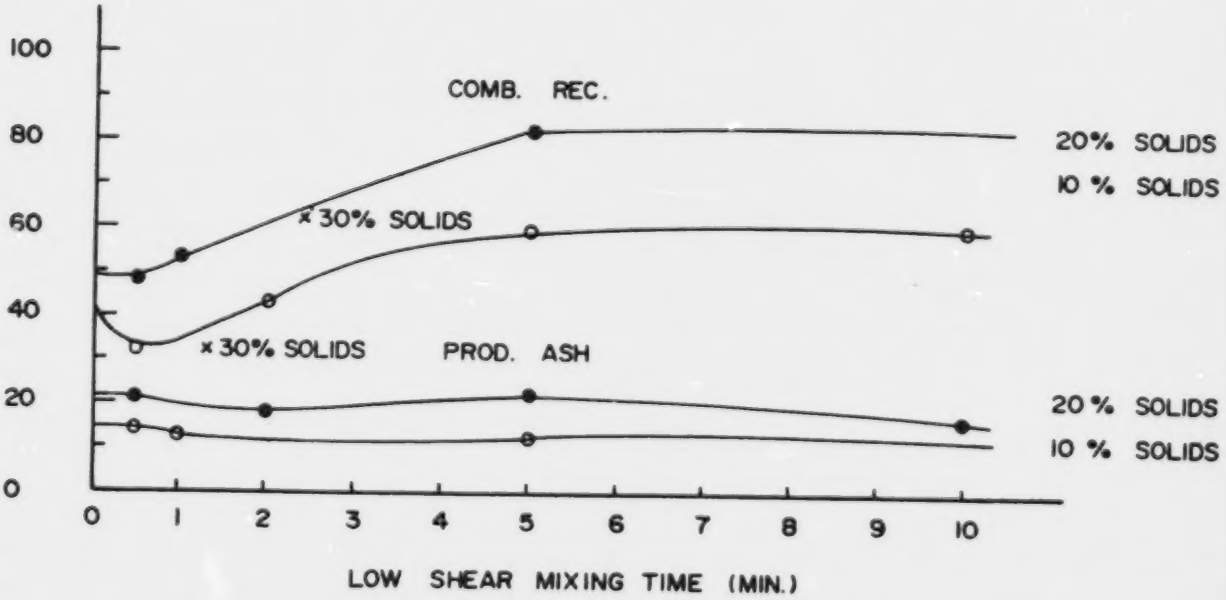
BATCH 2



FLOTATION CELL EFFLUENT

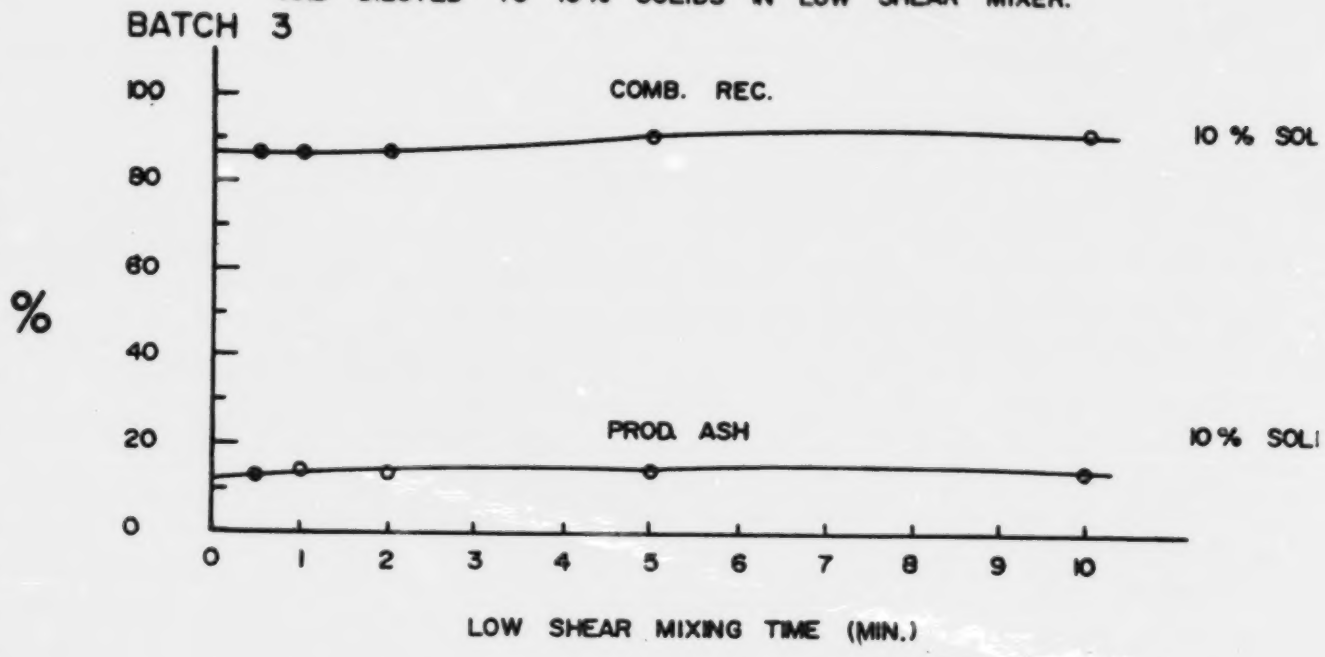
AGGLOMERATED WITH 1.0% #4 OIL AT 30% SOLIDS

BATCH 5



FLOTATION CELL FEED

AGGLOMERATED WITH 1.0% #4 OIL AT 30% SOLIDS
AND DILUTED TO 10% SOLIDS IN LOW SHEAR MIXER.



FLOTATION CELL EFFLUENT

AGGLOMERATED WITH 1.5% #4 OIL AT 30% SOLIDS
AND DILUTED TO 10% SOLIDS IN LOW SHEAR MIXER.

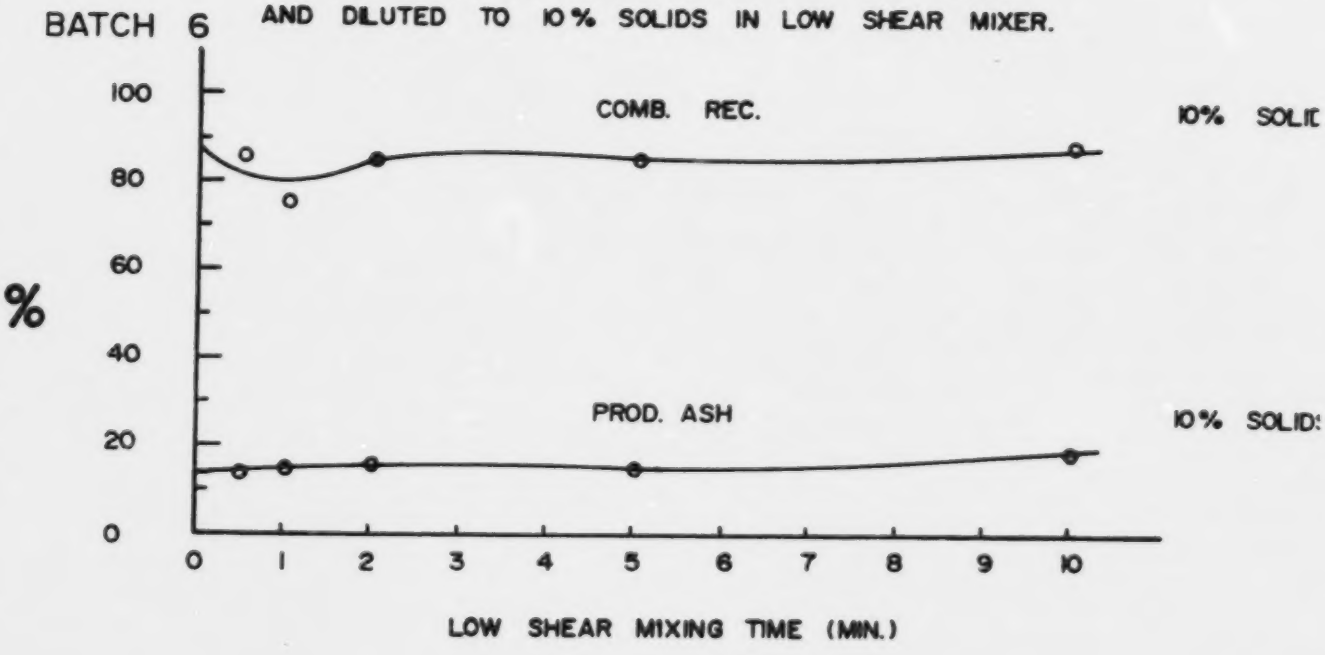


TABLE 3.2-7

FLOTATION CELL FEED - MASS BALANCE RESULTS
Agglomerated with 2.0% #4 oil
at 20% solids

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
7	0-A	2.00	2.83	19.61	4.03	70.77	92.91	85.15	64.20	37.37	41.44	38.77	6.39	19.58
7	0-B	2.00	3.09	13.46	3.70	64.68	91.64	85.54	77.63	36.79	47.59	38.92	6.47	10.55
7	1-A	2.00	2.88	19.27	4.38	69.51	92.68	85.47	66.05	38.89	41.18	39.46	6.91	19.48
7	1-B	2.00	3.07	13.70	3.41	65.21	90.72	83.46	76.47	30.96	48.16	37.97	5.96	10.93
7	2-A	2.00	2.85	19.18	4.01	70.28	93.03	85.69	65.39	39.34	42.36	38.95	6.47	19.65
7	2-B	2.00	3.06	14.22	3.60	65.29	91.61	85.23	76.11	35.95	47.74	38.87	6.32	11.31
7	5-A	2.00	2.90	19.23	3.97	68.92	92.35	85.17	66.63	37.29	43.72	39.72	6.52	19.85
7	5-B	2.00	3.06	14.00	3.47	65.36	91.25	84.44	76.17	33.23	47.91	38.40	6.07	11.10

TABLE 3.2-8

FLOTATION CELL FEED - MASS BALANCE RESULTS
Agglomerated with 2.0% #4 oil
at 20% solids

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
8	0-A	2.00	2.88	18.22	3.75	69.33	92.34	84.67	67.28	37.51	45.31	38.60	6.34	18.63
8	0-B	2.00	3.16	12.14	3.12	63.37	90.09	83.27	79.86	32.58	53.48	38.19	6.04	10.54
8	30-A	2.00	2.84	18.23	3.63	70.39	93.09	85.56	66.38	39.20	44.49	38.17	6.09	18.97
8	30-B	2.00	3.12	12.24	3.12	64.08	89.57	81.78	78.93	27.83	50.92	37.22	5.70	10.50
8	1-A	2.00	2.90	17.97	4.10	68.89	91.26	82.61	67.49	31.40	42.33	38.08	6.48	19.20
8	1-B	2.00	3.15	12.38	3.67	63.50	89.73	82.56	79.31	29.99	48.28	37.99	6.38	10.93
8	2-A	2.00	2.91	18.18	4.13	68.84	92.30	84.91	67.88	37.77	43.28	38.97	6.72	19.04
8	2-B	2.00	3.14	13.44	3.87	63.32	89.57	82.37	77.80	28.81	46.44	38.52	6.47	10.98
8	10-A	2.00	2.85	18.99	4.28	70.29	93.67	87.04	65.96	43.29	40.60	39.21	6.75	18.89
8	10-B	2.00	3.06	13.40	3.41	65.43	91.87	85.49	77.12	36.94	48.98	38.32	6.13	10.95

TABLE 3.2-9

FLOTATION CELL FEED - MASS BALANCE RESULTS
Agglomerated with 1.0% #4 oil
at 20% solids

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
9	0-A	1.00	2.07	12.92	2.91	48.22	66.53	59.21	83.11	11.01	65.59	36.89	5.62	18.36
9	0-B	1.00	2.39	9.49	2.78	41.87	58.59	53.92	88.75	8.90	69.32	35.32	5.32	10.22
9	30-A	1.00	2.18	12.24	2.77	45.93	64.32	58.65	84.94	11.05	68.88	37.33	5.72	17.63
9	30-B	1.00	2.38	9.56	2.66	42.05	59.36	55.08	88.81	9.04	69.90	35.94	5.25	9.79
9	1-A	1.00	2.15	12.57	3.10	46.46	64.59	58.42	84.27	10.87	65.78	37.12	5.85	18.27
9	1-B	1.00	2.51	8.64	2.98	39.88	59.05	57.98	91.00	9.78	69.49	38.30	5.76	9.17
9	2-A	1.00	2.25	13.21	3.12	44.47	61.45	56.39	84.20	10.18	67.17	37.19	5.84	18.29
9	2-B	1.00	2.11	9.33	2.87	47.29	66.76	59.50	87.67	10.35	64.24	35.78	5.35	9.61
9	10-A	1.00	1.66	14.71	3.51	60.19	82.56	72.76	76.59	18.61	52.87	37.82	6.14	18.40
9	10-B	1.00	1.84	10.45	2.93	54.40	76.94	67.98	84.50	14.83	60.31	36.68	5.67	10.60

TABLE 3.2-10

FLOTATION CELL EFFLUENT - MASS BALANCE RESULTS
Agglomerated with 2.0% #4 oil
at 20% solids

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
10	0-A	2.00	3.40	20.96	4.88	58.83	87.86	84.40	73.81	34.68	49.51	47.08	8.50	18.73
10	0-B	2.00	3.61	15.87	4.17	55.40	84.62	81.01	80.43	25.33	52.45	44.92	7.42	10.28
10	30-A	2.00	3.47	20.20	4.29	57.69	87.22	84.02	75.48	31.60	51.99	47.10	7.78	18.00
10	30-B	2.00	3.54	16.44	4.52	56.42	86.21	82.69	79.53	27.61	49.41	45.31	7.71	9.94
10	1-A	2.00	3.37	21.66	4.74	59.30	88.07	84.53	72.81	32.13	47.90	47.25	8.00	18.24
10	1-B	2.00	3.60	16.15	5.14	55.51	84.73	81.15	80.11	24.77	46.48	45.07	8.14	10.15
10	2-A	2.00	3.56	19.99	4.31	56.11	85.43	82.55	76.36	28.25	52.78	47.44	7.80	18.01
10	2-B	2.00	3.62	15.20	4.26	55.20	84.45	80.77	81.18	24.44	51.38	44.58	7.39	9.92
10	5-A	2.00	3.38	21.65	4.93	59.21	88.89	85.78	73.19	40.65	50.78	47.81	8.90	18.96
10	5-B	2.00	3.62	15.49	4.12	55.18	85.56	82.44	81.21	27.45	52.94	45.50	7.49	10.30
10	10-A	2.00	3.47	19.70	4.48	57.70	86.65	83.12	75.57	29.27	50.15	46.53	7.79	18.01
10	10-B	2.00	3.80	13.39	3.33	52.66	83.38	80.80	84.43	22.81	57.75	45.30	6.56	9.88

TABLE 3.2-11

FLOTATION CELL EFFLUENT - MASS BALANCE RESULTS
Agglomerated with 2.0% #4 oil
at 20% solids

		Wt % Oil		Product				Tails						
Batch	Sample	d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.	% Ash in Feed	% S in Feed MM Free	Pulp Density
11	0-A	2.00	3.51	19.81	4.25	56.97	85.12	81.44	75.64	28.61	54.05	46.33	7.88	18.35
11	0-B	2.00	3.78	14.69	3.66	52.89	82.85	80.18	82.94	25.28	58.85	45.54	7.36	10.04
11	30-A	2.00	3.57	19.67	4.58	56.03	85.52	82.67	76.74	31.33	53.66	47.37	8.45	18.51
11	30-B	2.00	3.70	14.70	4.09	53.99	82.44	78.68	82.02	22.65	54.11	44.14	7.35	9.59
11	1-A	2.00	3.58	18.92	4.91	55.83	84.62	81.37	77.29	28.77	51.59	46.51	8.58	18.35
11	1-B	2.00	4.00	13.42	4.03	50.03	80.03	78.36	85.36	23.15	58.91	45.87	7.85	10.64
11	2-A	2.00	3.37	21.04	6.02	59.38	86.72	82.33	72.81	29.88	43.20	45.94	9.18	19.48
11	2-B	2.00	3.68	14.33	3.88	54.35	84.14	80.77	82.56	26.05	55.90	44.66	7.39	9.73
11	5-A	2.00	3.36	20.33	4.66	59.50	88.05	84.12	73.80	33.88	49.67	46.16	8.15	18.11
11	5-B	2.00	3.65	13.43	3.55	54.86	84.36	80.49	83.14	25.17	56.82	43.70	6.93	10.12
11	10-A	2.00	3.46	19.79	4.23	57.74	86.55	82.97	75.42	31.18	53.41	46.49	7.85	17.12
11	10-B	2.00	3.58	13.74	3.84	55.84	85.46	81.44	82.42	27.21	54.68	43.64	7.24	10.00

TABLE 3.2-12

FLOTATION CELL EFLUENT - MASS BALANCE RESULTS
Agglomerated with 1.5% #4 oil
at 20% solids

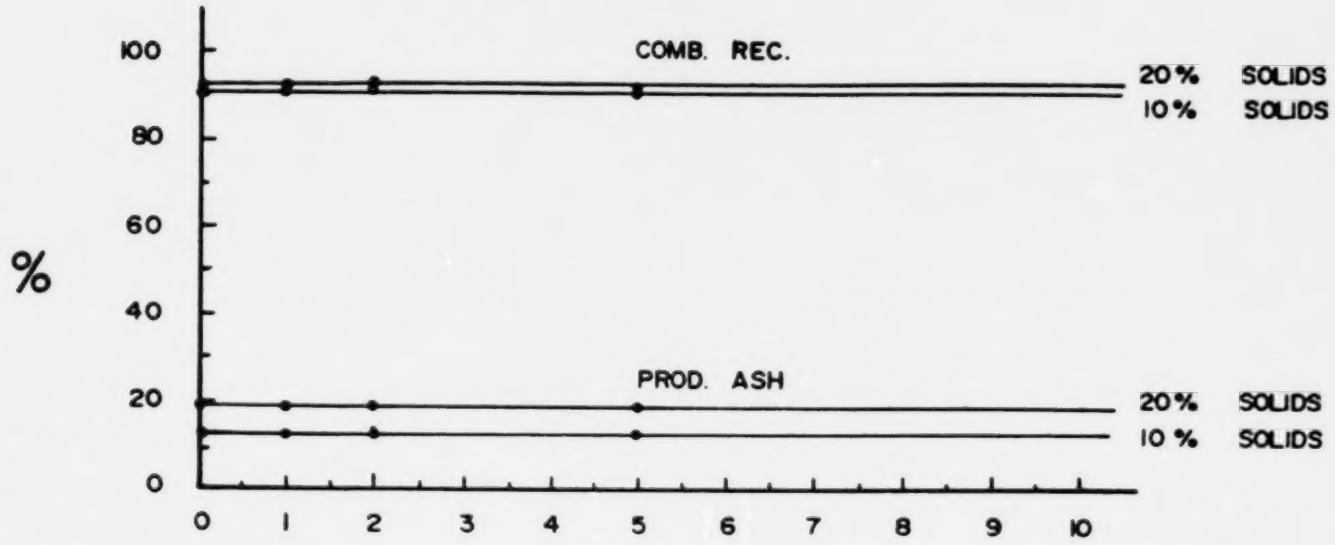
Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
12	0-A	1.50	5.61	14.77	3.27	26.73	45.02	62.04	92.01	12.59	82.45	49.41	8.40	18.20
12	0-B	1.50	4.61	10.54	2.81	32.53	54.93	64.60	92.71	12.43	78.43	47.01	7.14	9.21
12	30-A	1.50	5.81	14.38	3.36	25.80	42.99	60.51	92.37	11.72	82.22	48.61	8.13	18.24
12	30-B	1.50	3.25	10.49	2.76	46.21	67.03	62.17	87.34	11.29	66.80	38.29	5.57	11.19
12	1-A	1.50	9.02	14.40	2.53	16.64	31.16	62.27	95.59	11.41	75.79	54.31	6.17	16.97
12	1-B	1.50	4.00	9.15	3.49	37.50	59.02	62.15	91.88	12.75	88.96	42.27	9.86	10.06
12	2-A	1.50	5.17	14.35	3.26	28.99	48.33	62.61	91.44	12.60	80.52	48.62	8.08	18.09
12	2-B	1.50	3.73	11.36	3.46	40.21	67.51	71.32	90.33	16.18	69.21	47.21	7.59	9.52
12	5-A	1.50	3.94	14.98	3.25	38.05	66.52	73.72	88.91	19.71	75.35	51.37	8.76	16.16
12	5-B	1.50	4.98	10.44	2.56	30.11	51.72	63.98	93.43	10.24	78.90	47.86	6.27	7.73
12	10-A	1.50	3.90	14.57	3.35	38.43	64.11	70.15	88.52	16.31	73.18	48.79	8.00	17.40
12	10-B	1.50	4.49	10.07	2.57	33.40	58.96	68.60	93.14	14.75	79.99	49.05	7.57	9.31

FIG. 3.2-4

FLOTATION CELL FEED

AGGLOMERATED WITH 2.0 % #4 OIL AT 20 % SOLIDS IN HIGH SHEAR FOR 30 SECONDS

BATCH 7



FLOTATION CELL EFFLUENT

AGGLOMERATED WITH 2.0 % #4 OIL AT 20 % SOLIDS IN HIGH SHEAR FOR 30 SECONDS

BATCH 10

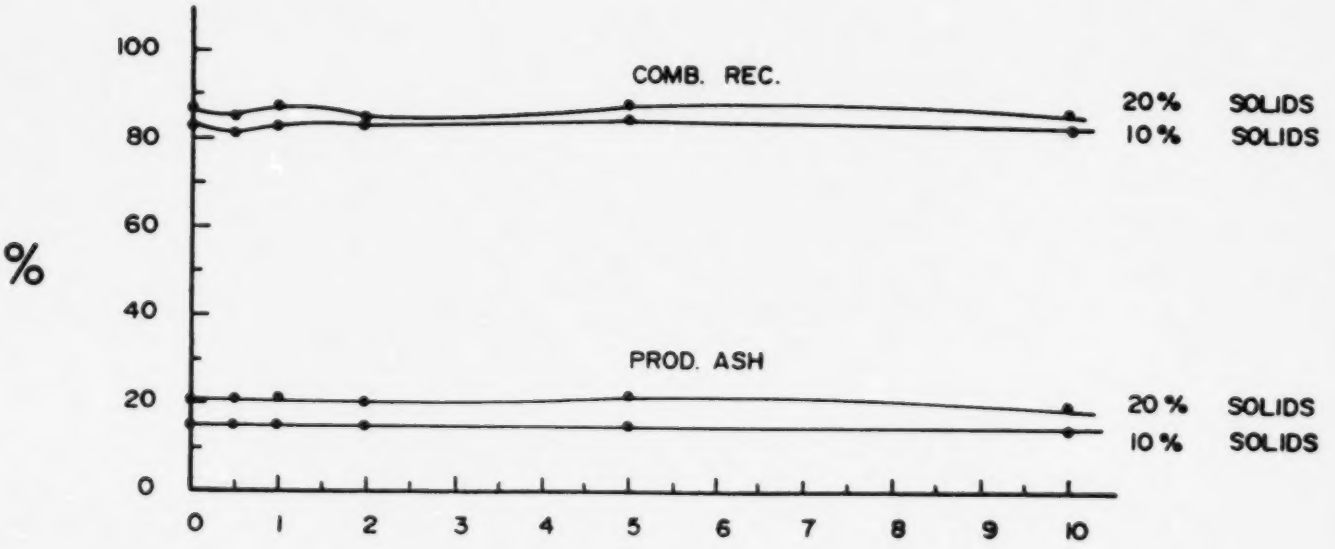
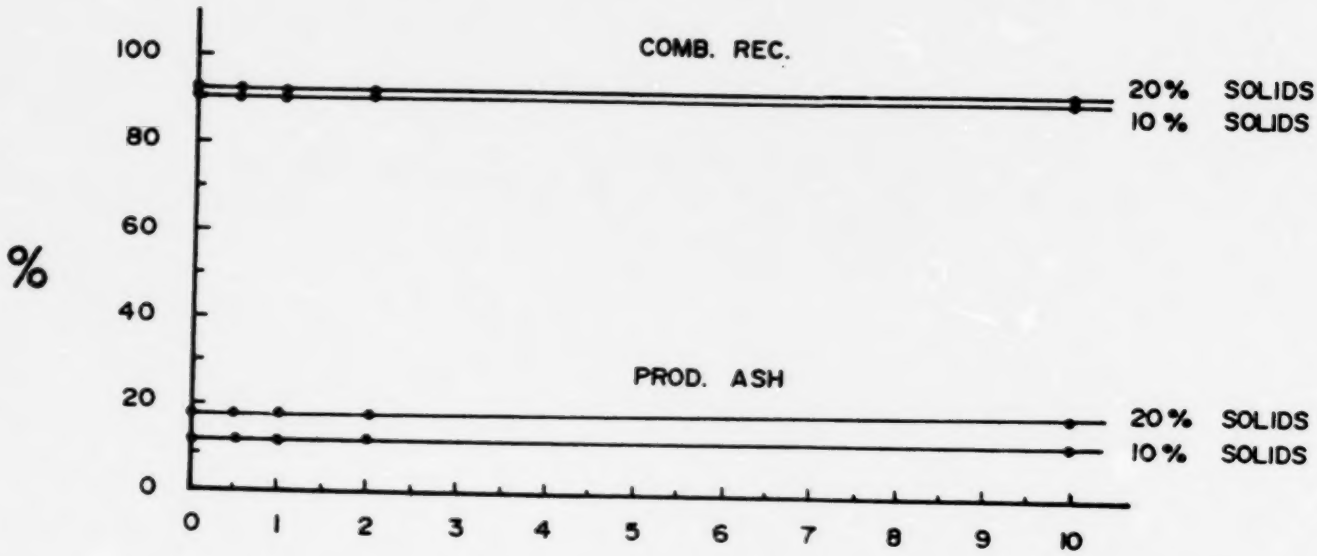


FIG. 3.2-5

FLOTATION CELL FEED

AGGLOMERATED WITH 2.0 % #4 OIL AT 20 % SOLIDS IN HIGH SHEAR FOR 15 SECONDS

BATCH 8



FLOTATION CELL EFFLUENT

AGGLOMERATED WITH 2.0 % #4 OIL AT 20 % SOLIDS IN HIGH SHEAR FOR 15 SECONDS

BATCH 11

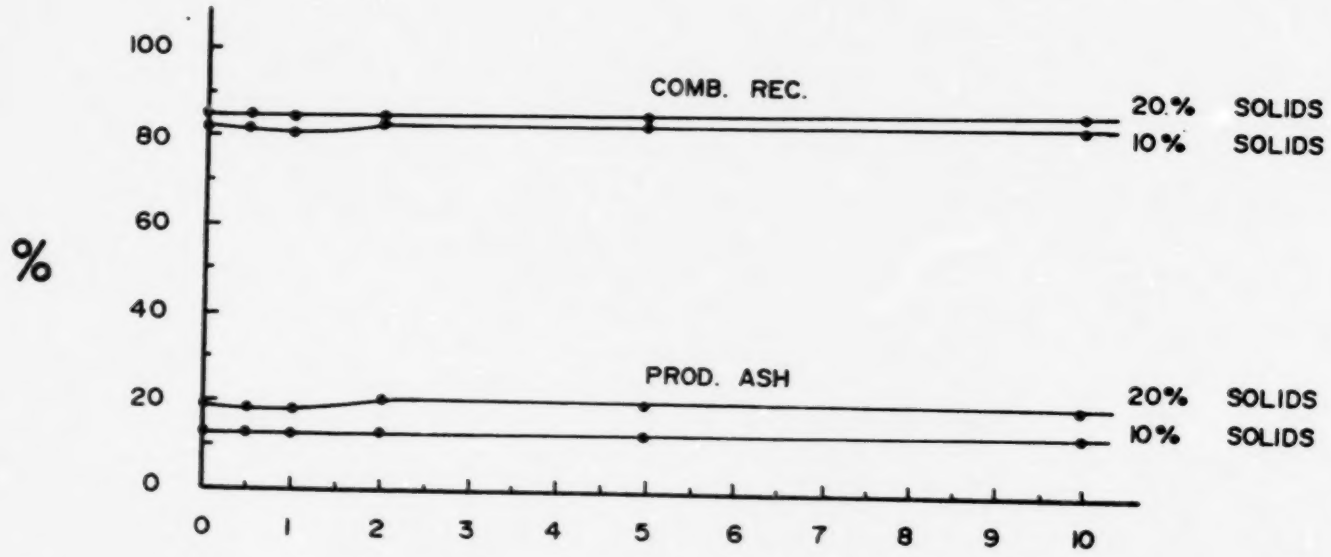
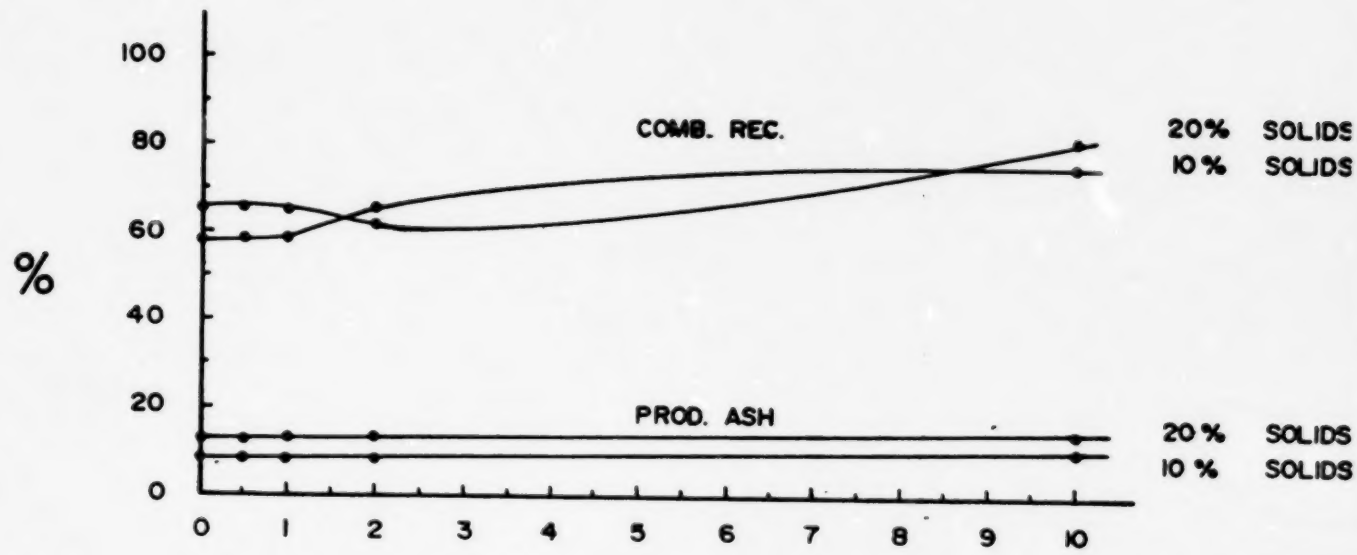


FIG. 3.2-6

FLOTATION CELL FEED

AGGLOMERATED WITH 1.0 % #4 OIL AT 20 % SOLIDS IN HIGH SHEAR FOR 15 SECONDS

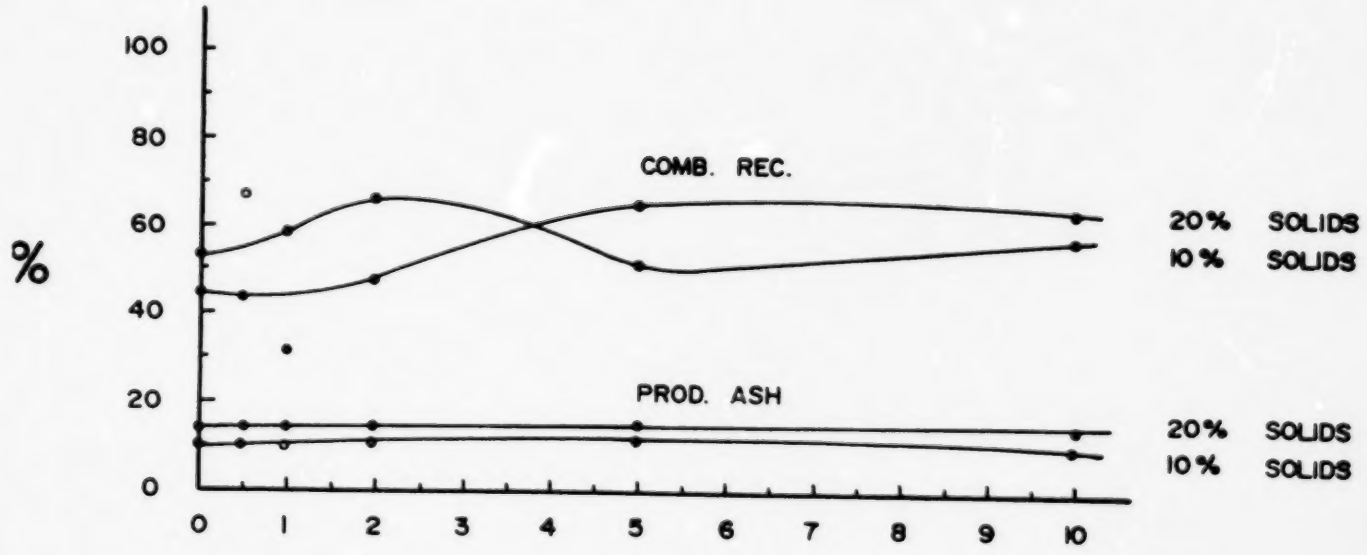
BATCH 9



FLOTATION CELL EFFLUENT

AGGLOMERATED WITH 1.5 % #4 OIL AT 20 % SOLIDS IN HIGH SHEAR FOR 15 SECONDS

BATCH 12



For the Float Cell Effluent (i.e. Batches 10, 11 and 12) a similar trend can be seen. Batch 10 shows combustible recoveries with little time dependence, Batch 11 recoveries are slightly more time dependent, and Batch 12 recoveries are fairly erratic.

It seems that a "breakpoint" has been reached in the agglomeration mechanism whereby the combination of reduced residence time in the high shear mixer and reduced oil content can only be overcome by extended residence times in the low shear mixer.

Bench scale results are quite dependent on the care with which the procedure is followed. The erratic result of Batch 12 may be partly due to inconsistencies in feed material, but may also have been caused by slight procedural differences.

The overall conclusions of this bench scale test program are:

- effective recovery of waste coal fines from the Prince Mine can be achieved, with good ash rejection, using the oil agglomeration and novel product recovery procedure. Residence times required for effective process performance are low.

- a small process unit can, therefore, handle relatively high solids throughput. For example, agglomeration of a 20% solids slurry of the Flotation Cell Feed, using 2% #4 oil and 15 seconds high shear retention time, provides good results. This is equivalent to a limiting solids throughput of 12 TPH in the high shear mixer. A rate of 8 TPH should be attainable on a continuous basis provided that protection is given for the abrasive wear on high shear internals.

Upon completion of the "routine" tests a bench scale evaluation of product washing procedures was performed.

The agglomerated slurry samples for Batches 1 through 12 were each processed through the bench recovery unit. The recovered product was then diluted in a Waring Blender, mixed for approximately two minutes and then screened on a 150 mesh screen. Moisture and ash analyses were performed on both recovered product and tailings.

In a separate test for Batch 11 only, the sample was again processed through the bench recovery unit. The recovered product was returned to the bench Unit, diluted with fresh water, mixed and then processed a second time. Moisture and ash analyses were performed on both recovered product and tailings.

The results of the wash and screen tests show good ash reduction. There was some loss of combustibles through the screen. This was attributed to the low physical strength of the low oil content product. The mass balance calculations can be found in TABLE 3.2-13.

TABLE 3.2-13a

"WASH AND SCREEN" RESULTS FOR BENCH SCALE AGGLOMERATE PROCESSING

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
1	9-B	1.00		6.38		93.47	97.32	63.15	40.90			10.09		12.12
2	19-A	1.00		7.68		84.89	93.24	62.42	59.12			15.95		13.97
2	19-B	1.00		5.85		91.23	94.67	44.82	42.42			9.27		12.65
3	26-B	1.00		5.94		91.12	94.74	46.40	43.21			9.53		12.82
4	31-B	1.00		8.92		86.55	94.70	67.18	53.93			16.76		9.17
4	32-B	1.00		10.23		89.63	96.00	67.60	43.34			16.19		9.18
5	38-A	1.00		8.48		87.71	95.21	67.10	52.57			15.68		10.94
6	42-B	1.50		8.48		88.54	96.06	70.96	51.99			15.64		8.48
6	44-B	1.50		10.25		89.43	96.08	69.00	44.32			16.46		8.08
7	47-B	2.00		7.65		92.08	97.61	73.70	45.31			12.88		9.42
7	48-A	2.00		11.13		90.39	98.24	84.98	44.80			18.22		10.18
8	52-A	2.00		9.60		89.18	97.25	78.94	49.94			17.10		11.18
8	52-B	2.00		7.78		95.60	99.19	83.66	33.12			11.12		10.04

TABLE 3.2-13b

"WASH AND SCREEN" RESULTS FOR BENCH SCALE AGGLOMERATE PROCESSING

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
8	54-B	2.00		8.99		94.90	98.80	79.42	32.19			12.58		10.12
9	58-A	1.00		7.08		90.57	96.34	66.09	49.29			12.65		10.92
9	60-B	1.00		7.18		94.61	97.73	62.15	33.01			10.14		10.80
5	36-B	1.00		7.53		91.57	96.71	65.77	44.56			12.44		7.93
10	65-A	2.00		12.48		87.40	97.02	81.37	48.45			21.16		10.49
10	66-B	2.00		13.60		93.98	98.57	80.46	27.46			17.62		12.40
11	67-A	2.00		12.05		88.48	96.97	78.87	46.00			19.75		10.23
11	70-A	2.00		11.06		87.27	96.79	79.80	51.27			19.81		9.52
12	76-A	1.50		7.64		85.91	91.86	50.13	51.85			13.62		11.52
12	78-A	1.50		7.47		90.03	96.52	69.81	50.87			13.70		10.91

The wash tests were performed on the Batch 11 sample. The initial recovery stage of each test was performed at 20% solids. The final recovery operation for Test #1 was performed at 20% solids. For Test #2 the solids content for the final recovery operation was 10 percent. TABLE 3.2-14 gives a brief summary of the mass balance calculations associated with the two tests.

Dilution to 10% solids for the second stage of product recovery gives the better ash content. Combustible recovery results are virtually identical for the two tests.

TABLE 3.2-14

WASH TEST RESULTS
USING NOVEL PRODUCT RECOVERY TECHNIQUES

Test	Prod Ash %	Comb Rec %	Tails Ash %	Ash Rej %	Pulp Density %
#1-Stage 1	19.32	83.79	83.37	80.20	20.94
#1-Stage 2	11.48	97.16	71.23	35.80	19.79
#2-Stage 1	17.34	81.88	82.22	82.99	15.71
#2-Stage 2	8.42	95.84	73.85	57.12	9.29

Product recovery occurs readily upon initiation of the bench recovery unit. In order to determine the rate of product recovery and to thereby establish the retention time required for optimal combustibles recovery a series of kinetics tests were performed.

The kinetics tests were performed on the 2 minute agglomerated slurry samples. It was expected that this retention time in the low shear mixer would give good carbon recovery. Tests were also performed on the 10 minute agglomerated slurry samples for comparison of mass balance results at longer retention times.

The analytical and mass balance results for the Kinetics testing are found in TABLES 3.2-15 through 3.2-23 inclusive.

TABLE 3.2-15a

FLOTATION CELL FEED - KINETICS
2 minute sample

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
1	2-C	1.00	1.64	13.72	3.04	36.26	51.24							
				14.49	3.14	51.36	71.93							
				14.86	3.14	61.07	85.16	76.72	76.70	24.01	57.12	38.94	6.24	18.49
1	2-D	1.00	1.72	10.09	2.93	47.46	69.10							
				10.26	2.86	54.35	78.99							
				10.44	2.84	58.19	84.40	76.96	84.12	22.27	59.18	38.25	5.87	11.26

FLOTATION CELL FEED - KINETICS
10 minute sample

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
1	10-C	1.00	1.48	16.27	3.74	45.27	61.20							
				16.30	3.83	60.81	82.19							
				16.66	3.86	65.98	88.78							
				17.04	3.89	67.74	90.73	82.20	69.67	31.85	45.52	38.06	6.49	19.43
1	10-D	1.00	1.58	10.77	3.44	50.06	71.51							
				11.68	3.48	58.99	83.41							
				12.14	3.49	61.50	86.51							
				12.78	3.53	63.26	88.33	80.17	78.46	27.13	50.38	37.54	6.28	10.39

TABLE 3.2-16a

FLOTATION CELL FEED - KINETICS
2 minute samples

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
2	2-D	1.00	1.64	16.75	3.15	30.06	59.98							
				16.67	3.15	45.62	60.73							
				16.75	3.15	54.50	72.48							
				16.62	3.13	61.10	81.39	70.05	72.86	17.46	56.03	37.40	5.80	25.63
2	2-E	1.00	1.65	9.28	2.70	39.25	54.61							
				9.42	2.66	52.76	73.30							
				9.84	2.65	60.45	83.60	72.96	82.91	15.46	53.38	34.80	4.75	10.21
3	2-B	1.00	1.70	10.12	2.90	47.13	68.76							
				10.15	2.87	54.62	79.65							
				10.33	2.85	58.83	85.63	78.50	84.18	23.67	58.25	38.39	5.84	10.52

TABLE 3.2-16b

FLOTATION CELL FEED - KINETICS
10 minute samples

Batch	Sample	Wt % Oil		Product				Tails						
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.	% Ash in Feed	% S in Feed MM Free	Pulp Density
2	10-D	1.00	1.42	18.40	3.98	44.40	57.58							
				18.18	4.04	61.79	80.34							
				18.35	4.07	68.08	88.34							
				18.64	4.09	70.47	91.10	81.04	64.56	28.16	40.22	37.07	6.23	20.81
2	10-E	1.00	1,58	12.35	3.38	43.58	61.74							
				13.13	3.45	56.58	79.45							
				13.89	3.47	61.32	85.35							
				14.27	3.49	63.29	87.69	79.26	76.32	25.02	50.11	38.13	6.15	11.81
3	10-B	1.00	1.55	13.35	3.55	55.64	79.80							
				13.66	3.51	61.90	88.47							
				14.46	3.57	64.70	91.61	85.64	76.37	35.10	47.40	39.59	6.21	10.84

TABLE 3.2-17a

FLOTATION CELL EFFLUENT - KINETICS
2 minute samples

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
4	2-C	1.00	2.26	15.69	3.75	28.05	43.86							
				15.72	3.60	37.69	58.92							
				15.74	3.52	40.60	63.44							
				15.95	3.53	44.16	68.84	69.91	84.71	16.05	67.30	46.08	7.43	17.78
4	2-D	1.00	2.28	11.32	3.30	30.96	49.63							
				11.49	3.22	38.06	60.89							
				11.84	3.17	43.77	69.75	70.24	88.40	14.65	66.71	44.68	6.64	10.02

TABLE 3.2-17b

FLOTATION CELL EFFLUENT - KINETICS
10 minute samples

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
4	10-C	1.00	1.63	20.20	4.20	37.75	54.31							
				20.58	4.32	51.69	74.00							
				21.60	4.42	57.57	81.35							
				22.40	4.47	61.25	85.67	79.49	69.18	25.40	48.72	44.52	7.47	17.82
4	10-D	1.00	1.45	14.35	3.53	48.57	65.31							
				15.78	3.56	60.19	79.59							
				16.81	3.61	64.83	84.68							
				17.82	3.67	68.84	88.83	77.16	66.21	20.53	41.31	36.31	5.56	13.92

TABLE 3.2-18a

FLOTATION CELL EFFLUENT - KINETICS
2 minute samples

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
5	2-D	1.00	3.84	14.43	2.94	8.82	13.64							
				14.88	2.93	15.85	24.39							
				15.06	3.03	26.04	39.99	55.12	91.22	9.25	82.06	44.69	6.76	17.57
6	2-B	1.50	2.72	14.76	4.50	45.81	69.30							
				14.82	4.35	52.56	79.45							
				14.95	4.29	55.18	83.28	78.98	81.10	25.17	54.06	43.65	7.78	11.58

TABLE 3.2-18b

FLOTATION CELL EFFLUENT - KINETICS
10 minute samples

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
5	10-C	1.00	2.34	19.15	3.88	21.76	31.50							
				19.38	3.88	30.39	43.87							
				19.38	3.80	35.84	51.73							
				19.84	3.81	42.79	61.41	62.33	80.78	12.69	67.65	44.15	7.23	18.96
6	10-B	1.50	2.39	15.76	4.34	53.53	77.75							
				16.29	4.31	59.74	86.23							
				17.12	4.34	62.87	89.86	84.16	74.38	30.37	44.11	42.01	6.98	11.18

TABLE 3.2-19

FLOTATION CELL FEED - KINETICS
2 minute samples

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
7	2-C	2.00	2.80	18.94	3.91	47.26	62.52							
				19.36	4.21	61.65	81.14							
				19.42	4.28	68.81	90.50							
				19.48	4.33	71.38	93.82	86.78	64.11	41.75	38.82	38.73	6.64	20.90
7	2-D	2.00	3.08	12.24	3.69	55.22	78.19							
				12.55	3.67	62.00	87.48							
				13.08	3.70	64.85	90.93	84.01	77.68	32.46	46.66	38.02	6.31	11.29

TABLE 3.2-20

FLOTATION CELL FEED - KINETICS
2 minute samples

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
8	2-C	2.00	2.89	16.30	3.44	43.38	58.43							
				16.87	3.73	60.16	80.48							
				17.04	3.80	66.40	88.63							
				17.26	3.83	69.16	92.07	84.03	68.46	34.19	43.46	37.86	6.24	18.69
8	2-D	2.00	3.10	12.09	4.04	54.92	76.36							
				12.57	4.07	61.37	84.87							
				12.91	4.09	64.54	88.90	80.21	77.34	25.16	43.45	36.77	6.43	10.05

TABLE 3.2-21

FLOTATION CELL FEED - KINETICS
2 minute samples

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
9	2-C	1.00	2.39	12.47	2.89	20.88	29.17							
				12.75	2.85	35.05	48.73							
				13.16	2.93	41.84	57.98	54.74	85.26	9.68	70.54	37.34	5.76	18.08
9	2-D	1.00	2.24	9.25	2.58	27.07	39.50							
				9.49	2.56	35.49	51.65							
				9.92	2.59	44.96	65.11	60.57	88.20	11.08	69.63	37.80	5.55	9.51

TABLE 3.2-22

FLOTATION CELL EFFLUENT - KINETICS
2 minute samples

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
10	2-C	2.00	3.40	18.89	4.48	38.16	57.04							
				19.28	4.61	48.72	72.47							
				19.51	4.64	55.92	82.94							
				19.68	4.65	58.91	87.19	83.08	74.65	29.20	47.99	45.74	7.79	18.29
10	2-D	2.00	3.70	14.41	4.18	44.89	69.45							
				14.57	4.13	51.03	78.81							
				15.04	4.12	54.06	83.03	79.56	81.80	22.21	52.43	44.68	7.19	9.62

TABLE 3.2-23

FLOTATION CELL EFFLUENT - KINETICS
2 minute samples

Batch	Sample	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
11	2-C	2.00	3.38	19.32	4.61	33.65	49.76							
				19.45	4.61	48.80	72.05							
				19.68	4.61	56.90	83.77							
				19.81	4.61	59.14	86.93	82.54	74.22	31.62	50.79	45.44	8.14	18.21
11	2-D	2.00	3.81	13.33	3.89	43.29	67.42							
				13.58	3.83	49.74	77.24							
				13.79	3.83	52.55	81.40	78.19	83.67	22.79	57.64	44.35	7.35	9.50
12	2-C	1.50	6.16	13.27	3.21	11.59	19.96							
				13.41	3.02	16.19	27.82							
				13.91	3.06	24.36	41.62	61.11	93.17	12.11	84.72	49.61	8.35	17.22

The results under the PRODUCT heading are cumulative results. That is, the first row of numbers represent the product recovered from time=0 to time=30 sec. The second row represents the product recovered from time=0 to time=60 sec. (cumulation of 0-30 and 30-60 sec. products) and so on.

The tests that only show three rows of mass balance results combine the 60-90 second and 90-120 second products. In these cases the amount of recovered product in either of the individual time intervals would not have been sufficient for all analyses to be performed.

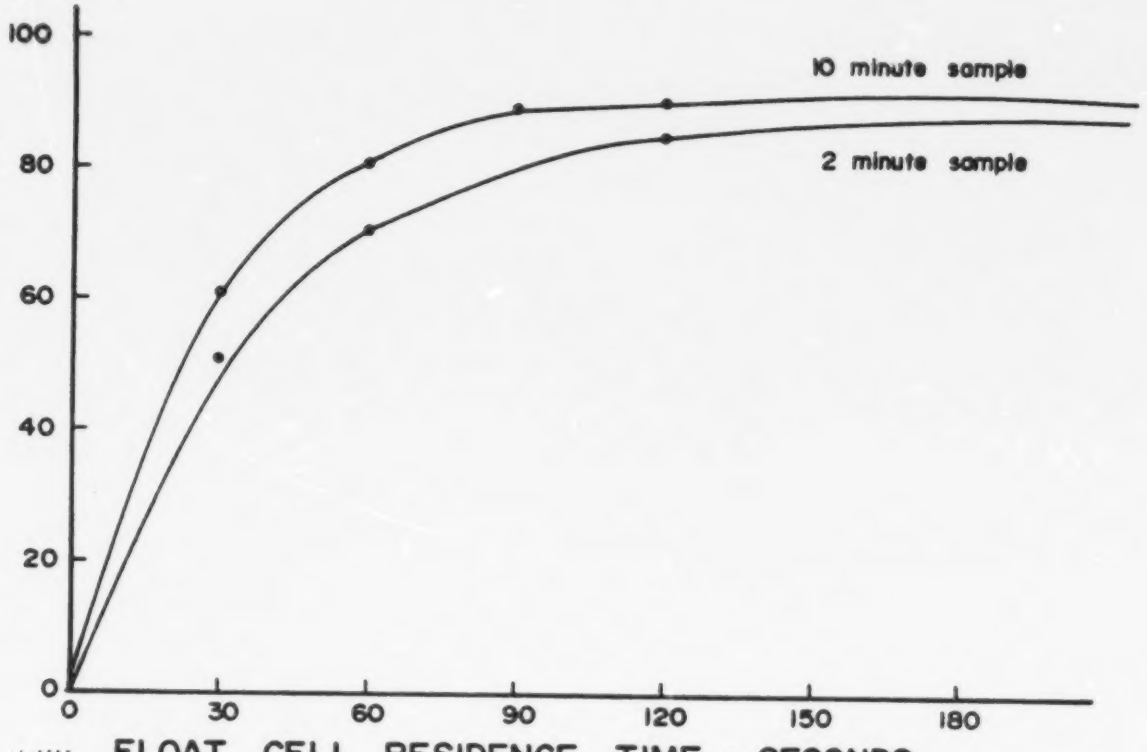
Selected kinetics results are shown graphically in FIGURE 3.2-7. Various batches and solids loadings are compared by their combustible recovery versus time curves. The results show that after 90 seconds residence time in the bench recovery unit combustible recovery is near maximum.

The kinetics tests for Batches 1 to 6 were performed on the 10 minute sample as well as the 2 minute sample withdrawn from the low shear mixer. The 10 minute samples were tested immediately after sampling. Testing of the 2 minute samples was delayed by several weeks. The poor combustibles recovery on the 2 minute samples indicate that a change in hydrophobicity of these samples had taken place during the week period between sampling and testing.

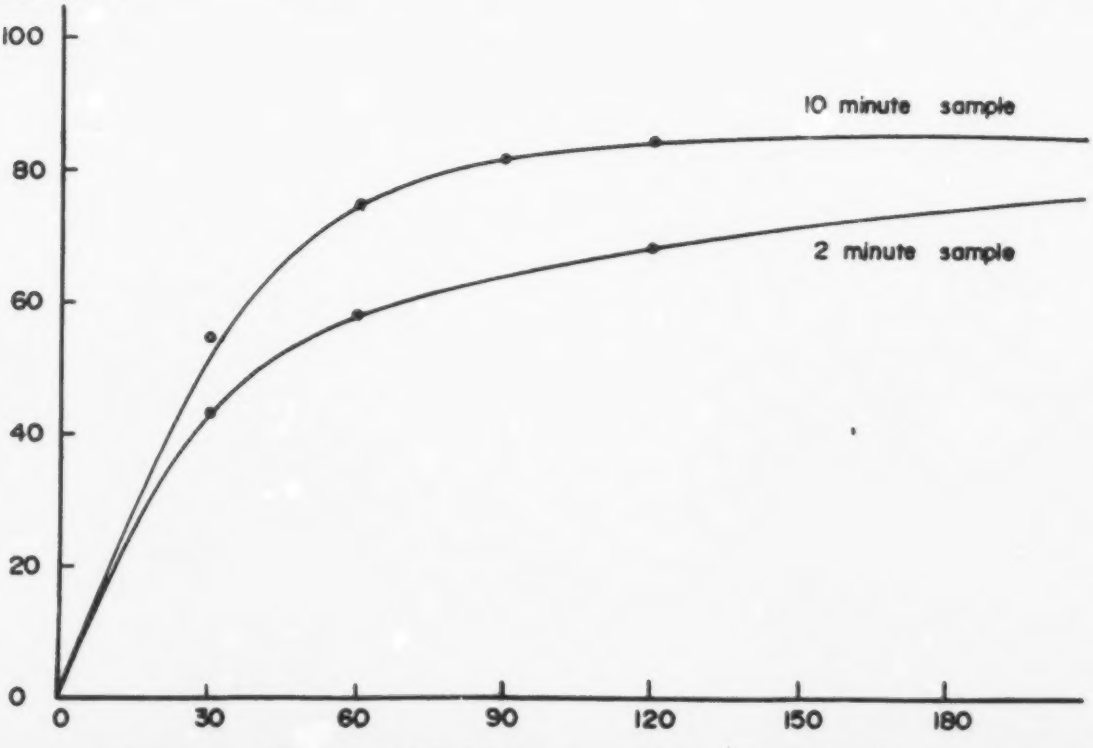
Combustible recovery figures for the 2 minute sample should be nearer to the recoveries achieved on testing of the corresponding 10 minute sample.

KINETICS – SELECTED RESULTS

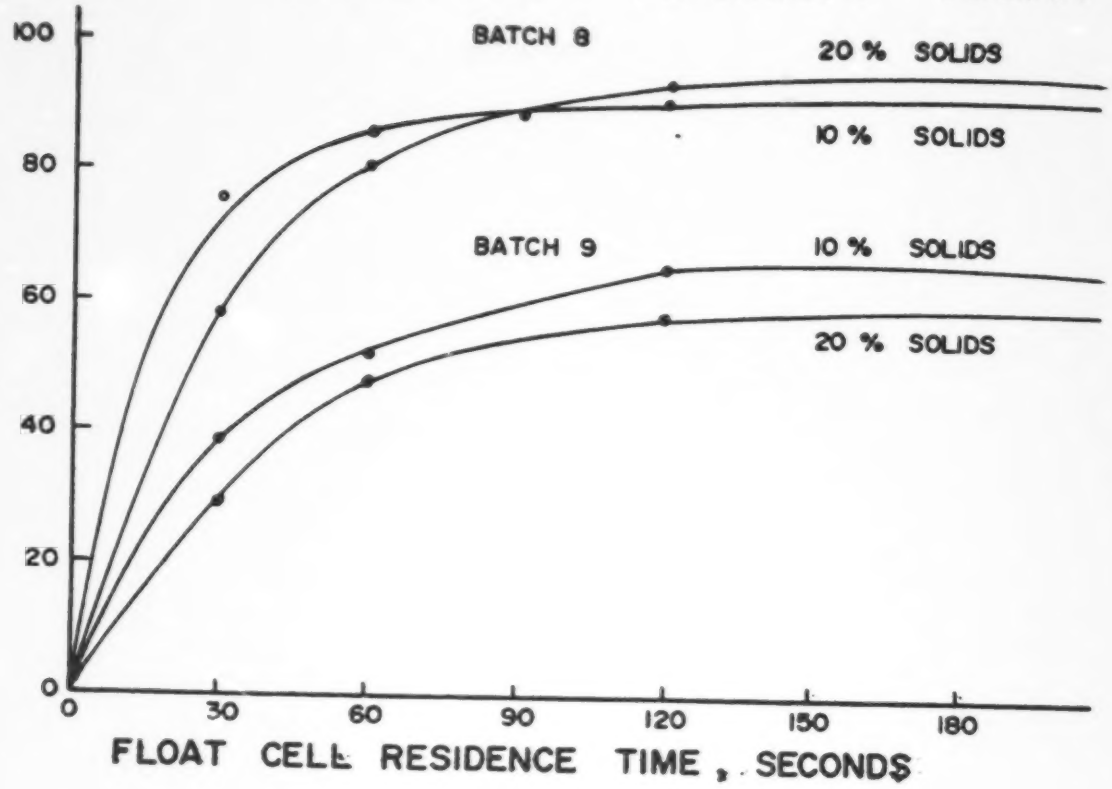
BATCH 1

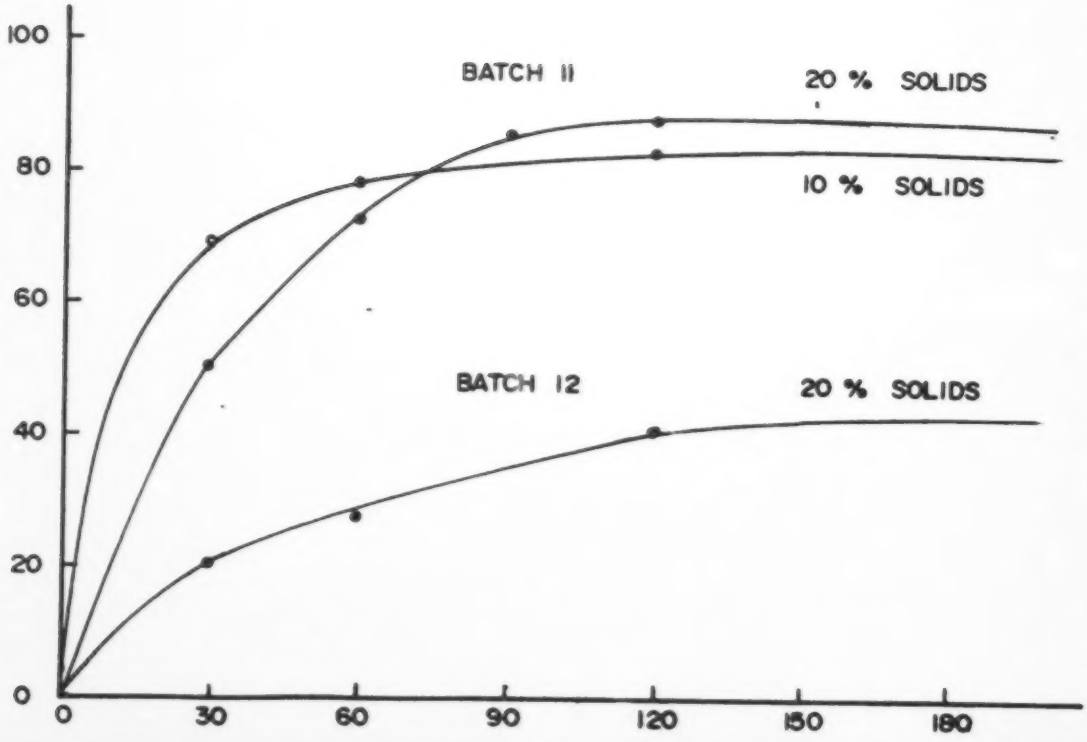


BATCH 4



KINETICS — SELECTED RESULTS (CONT'D)





3.2 Plant Scale Tests

Following the bench scale evaluation of the novel product recovery process, its kinetics and the value of an additional wash step the balance of each prepared batch was processed at plant scale.

Towards the end of the program, a continuous, pilot scale product recovery unit was made available for test.

This section will describe the results obtained in both the batch equipment and the continuous unit.

In the batch equipment each batch prepared was processed in two stages. The first 180-200 gallons were processed at the same solids content as was used in the preceding low shear mixing stage. The remaining 70-90 gallons were diluted with fresh water and processed at roughly one half that solids concentration.

TABLE 3.2-24 presents the analytical results of the pilot plant scale batch process. The first row of data under each new batch heading presents the solids and ash contents for the batch slurry prior to agglomeration.

In Batch 1 only, the effectiveness of product recovery using a 105 mesh screen was compared to the novel recovery procedure. These results are also presented in TABLE 3.2-24. The slurry dewatered very poorly. Ash content of the recovered screened product was 27.39%. By contrast, ash content of the recovered product using the confidential techniques was 12 - 15%. This confirmed the laboratory indication that agglomerate recovery by the screening method is inferior to the new procedure.

For the remaining batches, 2 through 12, the results indicate that ash rejection was more effective when the recovery procedure was completed at the lower solids levels.

The effectiveness of combustible recovery was proven by the high ash content of the tailings samples. Tailings ash was generally greater than 80%.

For batches 3 and 6, the incoming feed from the low shear mixer was at 30% solids. Slurry handling difficulties were experienced. Combustible recoveries were lower than anticipated. Batches 7 through 12 were, therefore, tested at 20% solids throughout the high shear/low shear mixing operation.

TABLE 3.2-24

Analytical Results of Plant Scale Testing

BATCH NO.	SAMPLE	% SOLIDS		% ASH d.b.	% ASH AFTER WASH & SCREEN
		IN BATCH EQUIP.	IN SAMPLE		
1	Feed		21.73		
	Floc	20	72.64	15.44	5.68
	Floc	10	72.41	12.60	5.28
	Screened	20	72.65	27.39	
2	Feed		29.53	39.43	
	Floc	30	73.33	13.42	5.69
	Tails	30	74.46	75.34	
	Floc	15	73.76	10.70	
	Tails	15	74.32	80.18	
3	Feed		29.90	43.05	
	Floc	10	72.72	10.37	5.78
	Tails	10	77.01	79.46	
	Floc	5	73.43	8.43	6.51
	Tails	5	76.64	81.76	
4	Effluent		18.56	48.18	
	Floc	20	70.98	15.25	9.87
	Tails	20	76.62	80.75	
	Floc	10	70.46	11.13	
5	Effluent		27.98	46.81	
	Floc	30	73.09	12.42	5.31
	Tails	30	74.24	81.25	
	Floc	15	72.89	10.66	
	Tails	15	66.02	72.10	
6	Effluent		29.21	49.78	
	Floc	10	72.55	11.44	
	Tails	10	73.93	80.68	
	Floc	5	72.30	8.48	6.93

TABLE 3.2-24 (Cont'd)

Analytical Results of Plant Scale Testing

BATCH NO.	SAMPLE	% SOLIDS		% ASH d.b.	% ASH AFTER WASH & SCREEN
		IN BATCH EQUIP.	IN SAMPLE		
7	Feed		22.53	43.72	
	Floc	20	74.21	14.61	7.18
	Tails	20	73.20	83.10	
	Floc	10	73.03	8.36	
	Tails	10	74.05	81.27	
8	Feed		19.48	41.65	
	Floc	20	75.37	13.41	6.98
	Tails	20	66.92	74.39	
	Floc	10	72.93	8.82	
	Tails	10	74.70	75.62	
9	Feed		19.41	39.95	7.24
	Floc	20	73.61	11.37	
	Tails	20	73.79	77.58	
	Floc	10	70.04	6.94	4.69
	Tails	10	72.02	67.30	
10	Effluent		20.35	48.49	
	Floc	20	79.96	13.46	5.93
	Tails	20	74.13	73.37	
	Floc	10	82.28	9.71	7.02
	Tails	10	71.33	80.00	
11	Effluent		18.28	46.26	
	Floc	20	76.19	15.71	10.48
	Tails	20	74.14	80.33	
	Floc	10	76.24	9.33	5.97
	Tails	10	73.93	81.81	
12	Effluent		17.86	50.83	
	Floc	20	73.88	13.96	9.01
	Tails	20	74.69	81.65	
	Floc	10	73.57	8.63	4.84
	Tails	10	75.59	80.35	

Batches 7 through 12 were used to evaluate the effect of reduced residence time in the high shear mixer. Anticipating a requirement for a higher level of agglomerating oil at these reduced residence times the oil addition rate was varied from 1.0% to 2.0% for the Float Cell Feed samples, and from 1.5% to 2.0% for the Float Cell Effluent samples.

The recovered product from the batches run at 2.0% oil was difficult to dewater on the vacuum screen. The agglomerates produced at this oil level may have entrained fine ash which would foul the screen and hamper the dewatering process.

The results of Batches 8 and 9 indicate that combustibles recoveries dropped slightly with the shorter high shear residence time. This effect is not clearly established in the results of Batches 11 and 12.

Throughout this phase of the plant scale work, Batches 1 through 12, the impact of a simple wash step was also evaluated. A portion of the recovered product was reslurried in fresh water to 10% solids, mixed briefly at low speed in a Waring blender, and then screened at 150 mesh. The results, seen in the last column of TABLE 3.2-24, show a significant reduction in ash content after the washing step.

TABLE 3.2-25 presents the calculated mass balance results for the "wash and screen" operation just described. These results do not incorporate the mass balance figures for the combined primary recovery/ wash and screen operation.

In Section 2.2.4 the set-up and operation of the continuous processing unit was discussed. Due to both time constraint and the limited scope of the present contract work, only two batches of material (one of Float Cell Feed, one of Float Cell Effluent) were processed through the unit.

The first processed a 10% solids, 1% #4 oil agglomerated slurry of Float Cell Feed material. The test was done in two parts. For the first portion of the test, solids feedrate was less than one-half ton per hour. For the second portion of the test this feedrate was increased to 1.25 TPH. The 1.25 TPH feedrate was still well below the maximum capacity of the unit.

In the second test, which was again performed in two parts, the feedstock to the continuous unit was Float Cell Effluent, at a solids content of 10%, agglomerated with 1.5% #4 oil.

The feedrate for part one of the test was 1.25 TPH. The second part of the test was completed at 2.5 TPH. The slurry pumps handling the product were unable to maintain a higher production rate. It was apparent, however, that the unit had not yet reached its limiting rate.

"WASH AND SCREEN" RESULTS
FOR PILOT PLANT PROCESSED AGGLOMERATES

Batch	% Solids in Rect Tank	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
1	20	1.00		5.68		79.95	88.64	51.80	69.58			14.48		9.96
1	10	1.00		5.28		85.74	92.90	56.56	64.05			12.58		10.12
2	30	1.00		5.69		86.31	91.88	47.41	56.97			11.40		10.07
3	10	1.00		5.78		86.13	89.12	28.59	44.30			8.94		8.64
3	5	1.00		6.51		87.64	89.08	18.74	28.92			8.03		8.27
4	20	1.00		9.87		86.25	91.19	45.39	42.28			14.76		10.09
5	30	1.00		5.31		88.53	94.87	60.63	59.81			11.68		10.16
6	5	1.00		6.93		95.52	97.50	49.28	24.94			8.82		10.27
7	20	1.00		7.18		90.65	97.11	73.26	51.27			13.36		10.14
8	20	1.00		6.98		89.79	97.49	78.92	56.25			14.33		9.712
9	20	1.00		7.24		89.80	94.16	49.30	43.60			11.53		10.42
9	10	1.00		4.69		93.38	95.35	34.50	34.28			6.66		9.73
10	20	2.00		5.93		90.80	97.92	80.31	57.85			12.77		10.00

"WASH AND SCREEN" RESULTS
FOR PILOT PLANT PROCESSED AGGLOMERATES

Batch	% Solids in Rect Tank	Wt % Oil		Product				Tails				% Ash in Feed	% S in Feed MM Free	Pulp Density
		d.b. feed	d.b. prod	% ash d.b.	% S d.b. MM Free	Mass Yield	Comb. Rec.	% ash d.b.	% Ash Rej.	% S d.b. MM Free	S Rej.			
10	10	2.00		7.02		95.67	98.23	63.05	28.89			9.44		10.45
11	20	2.00		10.48		89.97	94.66	54.67	36.76			14.91		10.29
11	10	2.00		5.97		95.08	97.58	54.91	32.35			8.38		10.36
12	20	1.50		9.01		88.77	94.47	57.92	44.84			14.50		9.96
12	10	1.50		4.84		94.85	97.77	60.08	40.28			7.69		10.17

TABLE 3.2-26 presents the analytical results obtained from the testing of the continuous product recovery unit.

Conclusions arising from the work with the continuous unit are as follows:

- The limiting feedrate for the unit tested was above 2.5 TPH, probably 4-5 TPH.
- A preferred design for the unit would allow product removal rates to double. Capacity to remove the recovered product should not be the limiting factor.

TABLE 3.2-26

SUMMARY OF ANALYTICALS FOR CONTINUOUS PRODUCT RECOVERY UNIT

TEST	SAMPLE	% SOLIDS	% ASH, d.b.
#1 - Part One	FEED	8.83	40.95
	PRODUCT	44.12	9.32
	TAILINGS	3.61	87.31
#2 - Part Two	FEED	8.83	40.95
	PRODUCT	37.78	7.92
	TAILINGS	3.91	77.00
#2 - Part One	FEED	9.91	46.43
	PRODUCT	42.00	13.00
	TAILINGS	5.41	88.19
#2 - Part Two	FEED	9.91	46.43
	PRODUCT	40.00	12.00
	TAILINGS	6.28	75.98

4.0 Observations

The solids content of the samples as received from the Homer City Coal Cleaning Test Facility was quite consistent. The range in solids concentration was 69 - 71% by weight. The ash content of the solids fraction of either sample was less consistent. For the Float Cell Effluent sample the ash content covered the range of 44 to 54%.

There were some large rocks present in both of the samples, with a greater number being noticed in the Float Cell Effluent sample.

Particle size analyses showed that the two samples were similar in both size and ash distribution.

The float/sink analysis showed that the ash present in both the Float Cell Feed and the Float Cell Effluent was liberated to a considerable extent. The effectiveness of agglomeration methods in beneficiating these fines confirmed this to be true.

The solid tailings from the agglomeration tests settled very quickly, producing a clear supernatent over the ash sludge.

The Float Cell Effluent recovered product proved to be more difficult to dewater than the Float Cell Feed product.

5.0 Conclusions

The conclusions of the laboratory portion of this study are summarized in the following points.

- the fine clay fraction of both samples presents problems when attempting to do wet or dry sieve analyses. The fine clay tends to blind the screens, thus producing unreliable results.

- the results of the wet sieve analyses clearly show that for both samples the -325 mesh material makes up approximately 40% of the sample and is comprised of 70%+ ash.

- the results of the float/sink analysis determined that the ash in both samples was mostly liberated and reported in the 1.6 SINK fraction. Therefore, grinding of the "as received" samples is not necessary to produce a product having less than 5% ash.

- the optimal result of the laboratory investigation was achieved on the Float Cell Feed sample. An ash reduction of 88.5% resulted from a test using 0.7% #4 oil and the new product recovery procedures. The product had an ash content of 5% at a combustibles recovery of 84%.

The pilot plant phase of this work program, using both bench scale and plant scale equipment and methods, has confirmed the effectiveness of the agglomeration method in the recovery and beneficiation of Preparation Plant Coal Fines from the Prince Mine.

Using a relatively simple three stage process approximately 90% of the combustible material can be recovered from either the Float Cell Feed or the Float Cell Effluent streams. The recovered product has an ash level of 5 to 7%. Feedstock ash levels were in the 40-55% range.

The three stage agglomeration procedure, comprising a high shear mixing step, an initial product recovery step and a final product recovery step, is considerably more effective in the treatment of the Homer City Float Cell Feed sample than the Float Cell itself appears to have been. The effluent stream from the agglomeration process has an ash content of approximately 80%. The ash content of the Homer City Float Cell Effluent sample was approximately 50%.

6.0 RECOMMENDATIONS

A more comprehensive evaluation of the agglomeration/proprietary product procedure is required. Sufficient sample to allow a full fledged continuous operating test must be provided for this next phase of work.

Finalized process design and equipment selection decisions could be made during this next phase, allowing the agglomeration procedure to be installed as the fines recovery unit for the Prince Mine.

A further area of process and product development is suggested. This would entail the preparation and combustion of dry agglomerates, briquets or slurry fuels from the recovered Prince Mine fines, thereby demonstrating several forms of profitable end use for the recovered product.

7.0 ACKNOWLEDGEMENTS

The agglomeration/novel product recovery procedure was developed and initially demonstrated for Prince coal in the Chemical Engineering Section of NRCC. The direction and guidance of the members of that Section throughout the present work are gratefully acknowledged, as are the loans of several items of laboratory and pilot plant equipment.

The provision of analytical support by the Atlantic Research Laboratory of NRCC is also gratefully acknowledged.